Technical Report GL-94-21
August 1994

AD-A283 993

(1)

US Army Corps
of Engineers
Waterways Experiment
Station

Performance of Special Graded Asphalt Cements

by Randy C. Ahlrich, Lee E. Tidwell, Gary L. Anderton

WES

Approved For Public Release; Distribution Is Unlimited

Prepared for U.S. Air Force Civil Engineering Support Agency

Technical Report GL-94-21
August 1994

Performance of Special Graded Asphalt Cements

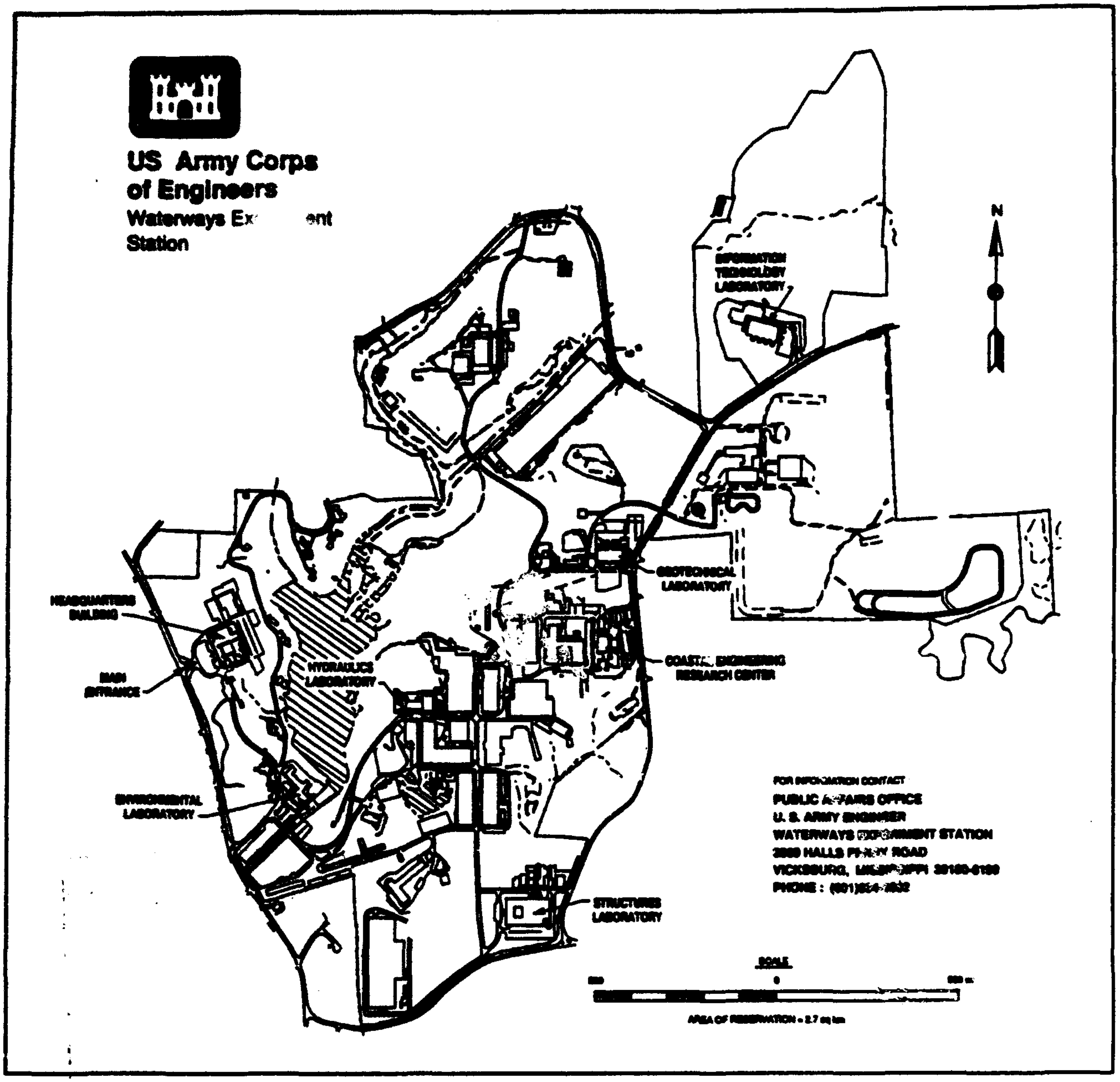
by Randy C. Ahlrich, Lee E. Tidwell, Gary L. Anderton

U.S. Army Corps of Engineers
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Final report

Approved for public release; distribution is unlimited

Prepared for U.S. Air Force Civil Engineering Support Agency
Tyndall AFB, FL 34203-6001



Waterways Experiment Station Cataloging-in-Publication Data

Ahlrich, Randy C.
Performance of special graded asphalt cements / by Randy C. Ahlrich, Lee E. Tidwell, Gary L. Anderton ; prepared for U.S. Air Force Civil Engineering Support Agency.
73 p. : ill. ; 28 cm. -- (Technical report ; GL-94-21)
Includes bibliographic references.
1. Pavements, Asphalt concrete -- Cold weather conditions -- Evaluation. 2. Runways (Aeronautics) -- Cold weather conditions -- Testing. 3. Pavements -- Performance -- Cold weather conditions. 4. Cement -- Cold weather conditions -- Evaluation. I. Tidwell, Lee E. II. Anderton, Gary L. III. United States. Army. Corps of Engineers. IV. U.S. Army Engineer Waterways Experiment Station. V. Geotechnical Laboratory (U.S.) VI. United States. Air Force Civil Engineering Support Agency. VII. Title. VIII. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; GL-94-21.
TA7 W34 no.GL-94-21

Contents

List of Figures

List of Tables

Preface

The investigation documented in this report was sponsored by the U.S. Air Force Civil Engineering Support Agency, Tyndall AFB, Florida. This work was conducted under Project Order Nos. 12/F88-60 and 12/F90-58, "Performance Survey of Special Graded Asphalts." Technical Monitor for this study was Mr. Jim Greene.

This study was conducted by personnel of the Pavement Systems Division (PSD), Geotechnical Laboratory (GL), at the U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, from December 1988 through September 1991. Mr. Randy C. Ahlrich was Principal Investigator. The report was written by Mr. Ahlrich, Ms. Lee E. Tidwell, and Mr. Gary L. Anderton. PSD personnel engaged in the laboratory testing included Messrs. Jerry Duncan, Herbert McKnight, David Reed, and Joey Simmons.

This study was conducted under general supervision of Dr. W. F. Marcuson III, Director, GL. Direct supervision was provided by Dr. G. M. Hammitt II, Chief, PSD, and Mr. T. W. Vollor, Chief, Materials Research and Construction Technology Branch.

The Director of WES during the preparation and publication of this report was Dr. Robert W. Whalin. The Commander was COL Bruce K. Howard, EN.

Conversion Factors, Non SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to metric units as follows:

Multiply	By	To Obtain
Fahrenheit degrees	(F-32)/1.8	Celsius degrees
inches	2.54	centimeters
pounds (force) per square inch	6.894757	kilopascals
feet	0.03048	meters
miles	1.60934	kilometers
pounds (force) per cubic foot	16.01846	kilogram per cubic meter

1 Introduction

Background

Low-temperature transverse pavement cracking is a serious asphalt pavement problem in the northern tier states, Alaska, Canada, and Greenland. The cracking occurs when thermal stresses induced in the pavement by cooling exceeds the tensile strength of the asphalt concrete. The crack begins at the asphalt concrete surface and progresses downward through the entire pavement layer. The initial occurrence of low-temperature cracks does not result in a major loss of pavement serviceability but will cause an accelerated loss of pavement performance over time leading to increased maintenance and a shortened pavement service life.

A major factor in the occurrence of low-temperature transverse cracking is the low-temperature stiffness of the asphalt cement. Low viscosity asphalt cements are recommended as binders in cold regions to reduce the potential for low-temperature cracking. The U.S. Army Corps of Engineers uses the penetration viscosity number (PVN) method in cold regions to aid in selecting an asphalt cement with reduced temperature susceptibility (see Appendix A, ETL 1110-1-139). The PVN criteria has been used by the U.S. Army Corps of Engineers for various Department of Defense agencies in cold regions since 1976. The PVN is an empirical correlation between asphalt cement factors and low-temperature pavement cracking experiences in Canada. In general, the greater or more positive the PVN, the less temperature susceptible the binder should be. Penetration data at 25 deg C and kinematic viscosity at 135 deg C are required to obtain the PVN. For road and airfield pavements, the U.S. Army Corps of Engineers specifies asphalts with a minimum PVN of -0.5 in moderately cold regions (northern tier states) and asphalts with a minimum PVN of -0.2 in severely cold regions (interior Alaska and Greenland). Asphalt cements meeting these criteria are termed "special graded."

Objective

The objective of this study was to evaluate the performance of special graded (arctic grade) asphalt cements in airfield pavements subjected to extreme cold conditions and to provide guidance on the use of these asphalt cements on DOD projects.

Scope

The scope of this study included a review of available literature and existing data, field site inspections, laboratory study and analysis of data. The effectiveness of special graded asphalt cements to minimize low-temperature cracking was evaluated at three locations, Wainwright Army Airfield, Alaska, Elmendorf AFB, Alaska, and Sondrestrom Air Base, Greenland. At each location a visual inspection was conducted to determine the amount and severity of cracking for pavements with standard and special graded asphalt cements. Field samples were also taken at each site to evaluate the properties of the in place asphalt concrete materials. From the data obtained in this investigation, recommendations and guidance are made concerning the use of special graded asphalt cements for DOD pavements.

2 Literature Review

In the cold regions of North America, pavements frequently suffer from low-temperature cracking that is caused by cyclic thermal stresses. Special graded asphalts are used by many pavement designers to reduce the effects of thermal stresses on asphalt concrete pavements. A brief literature review was conducted to determine the present state-of-the-art technology for using special graded asphalts in preventing damage from thermal stresses in asphalt pavements.

Canadian Study

McLeod (1976) reported a study on the Pen-Vis Number (PVN) and its application to pavement stiffness. The PVN is a temperature susceptibility procedure that is based on the penetration value of an asphalt cement at 25 deg C and its viscosity in centistokes at 135 deg C. This procedure was developed in response to the erroneous values that Pfeiffer's and van Doormal's penetration index (PI) would give to Canadian asphalts made from waxy crude oils that would show a false softening point. Because of the way the PVN was derived, the PVN and the PI are the same or very nearly so for many asphalt cements. This makes it possible to use PVN with Van der Poel's nomographs to obtain moduli of stiffness values for asphalt cements and asphalt paving mixtures.

NCHRP Study

The National Cooperative Highway Research Program (Finn et al 1978) reported a study on minimizing premature cracking in asphaltic concrete pavement. The objective of the research project was to prepare recommendations on materials, design, and construction requirements that could reduce the occurrence of premature low-temperature thermal cracking in asphalt concrete pavements. With respect to low-temperature cracking, it was reported that asphalt cement grade was the most viable designer-controlled factor related to low-temperature cracking. A low-viscosity asphalt should be used if premature low-temperature cracking is observed. Asphaltic concrete mixes made with low-viscosity asphalt cements are more easily compacted; thus, higher density requirements can be specified to achieve stabilities comparable to mixes made with harder asphalts.

Asphalt Institute Study

The Asphalt Institute reported a state-of-the-art literature review on low-temperature transverse cracking in asphalt concrete pavements (AI 1981). The report included an interpretation of the significant literature, guidelines for the application of current technology, and a framework for future advances in this area. The goal of this study was to find an economic way of minimizing the problem of low-temperature transverse cracking, i.e., retard the onset of cracking, and when it does occur, keep the cracking at an acceptable level.

Asphalt pavement transverse cracking is a regional problem, with more severe cracking occurring in the coldest regions. The literature listed a number of factors that influence the occurrence and severity of pavement transverse cracking. They include climatic effects, subgrade type, asphalt cement properties, mix properties, pavement design, pavement age, and traffic effects. Low-temperature pavement design procedures have focused on asphalt cement or mix stiffness for controlling transverse cracking. The methods developed to predict cracking from asphalt cement or mix stiffness were based on identifying the "predicted cracking temperature" of the pavement. However, there was a lack of comprehensive data that correlated the predicted cracking temperatures with actual field data.

The report recommended the following basic steps for the development and application of a simple low-temperature pavement design procedure:

a. Determine the pavement design temperature. The pavement design temperature can be considered equal to the minimum pavement-surface temperature.

b. Predict pavement cracking temperature. Pavement cracking temperatures are estimated from the asphalt properties using the nomographic cracking temperature method shown in Figure 1.

c. Select a low-viscosity asphalt grade for low-temperature performance when the predicted pavement cracking temperature falls below the pavement design temperature.

d. Select asphalt for optimum overall pavement structural design if there is a conflict between the requirements of an acceptable low-temperature design and a sound pavement structural design.

The Asphalt Institute concluded that controlling low-temperature pavement transverse cracking by restricting asphalt properties in specifications has only been partly successful. The following recommendations were made:

a. Research projects should be initiated to measure the influence of mineral filler in the mix, subgrade effects, pavement thickness, etc. to determine the effect on low-temperature transverse cracking.

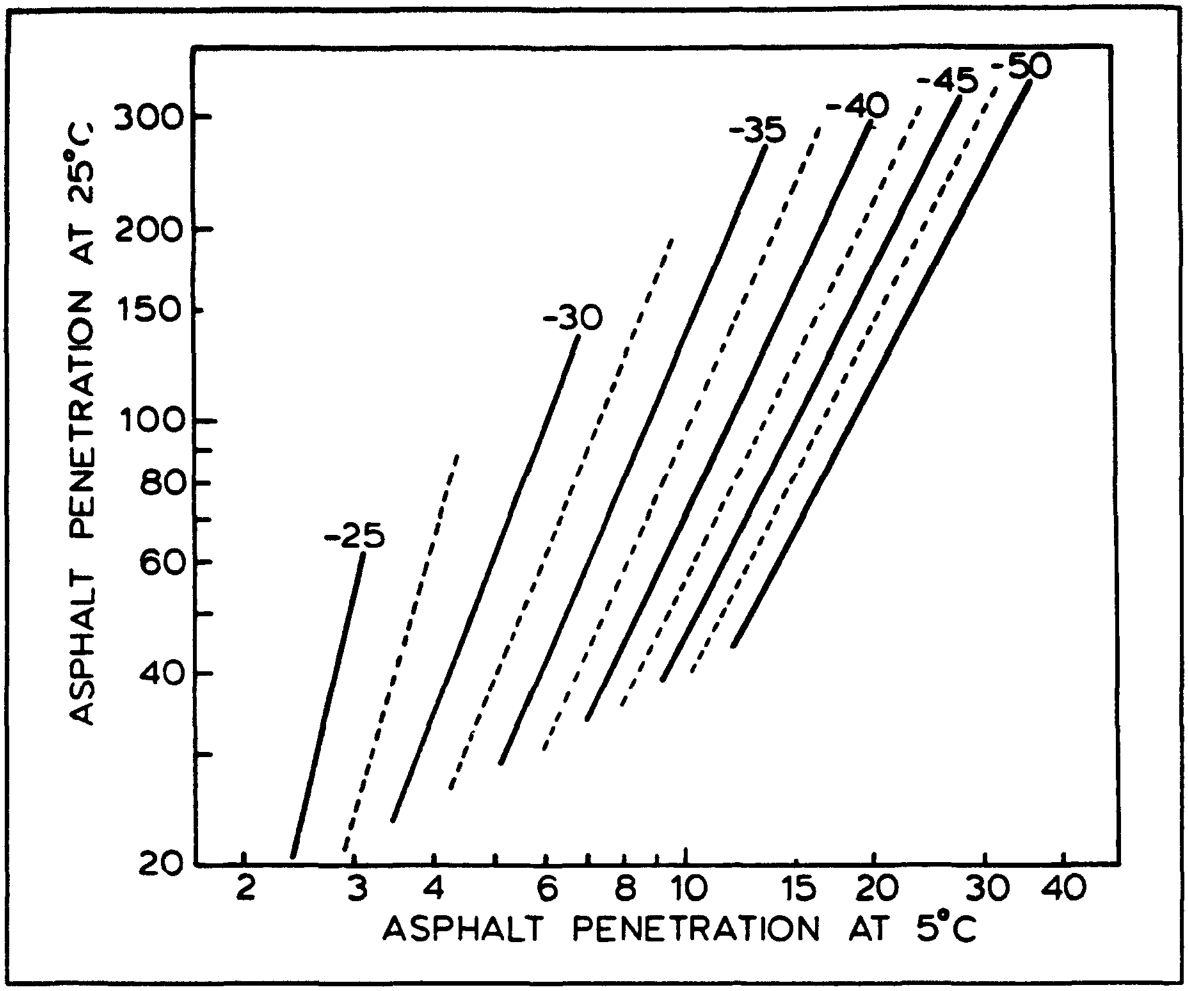


Figure 1. Nomograph for predicting cracking temperatures

b. Information from test roads and construction projects should be taken to include the effect of a wider variety of asphalts and other significant design variables.

c. The pavement design criteria should be used as a design procedure and not as an additional asphalt specification.

d. The design procedure based on cracking temperatures predicted from asphalt penetrations at 25 deg C and 5 deg C should be used as an interim guide to design pavements to resist low-temperature transverse cracking.

e. A modification of the American Society for Testing and Materials (ASTM) Standard Test Method D 5 should be proposed and developed to measure the penetration at 5 deg C, using for all measurements the 100 g, 5 sec test condition.

TRB Study

A state-of-the-art report on low-temperature properties of asphalt paving cements was published by the National Research Council and the Transportation Research Board (TRB 1988). This report provides references for nine test parameters (penetration, ductility, viscosity, glass transition temperature, tensile strength of thin films, absolute-rate theory and asphalt fracture, viscoelastic properties, asphalt stiffness, and modified asphalts) that pertain to low-temperature properties of paving asphalts. Paving asphalt specifications that use penetration measurements at lower temperatures have been recommended to improve low-temperature performance. Halstead (Halstead 1963) demonstrated that pavements containing asphalts with satisfactory penetration (30-50) at 25 deg C, 100 g, 5 s but with low ductilities at 25 deg C showed poorer service than pavements containing asphalts of the same penetration but with high ductility. Studies have also shown poor correlations between initial viscosity and penetration or ductility values and that these relationships become poorer with decreasing temperatures. This is due to the unknown and variable shear rates associated with these empirical tests at low temperatures. The selection of an asphalt cement that will resist cold weather cracking should depend on a direct measurement of low-temperature consistency. Viscosity, because of its fundamental nature over a wide range of temperatures, would be suitable for that purpose. Commonly used asphalt stiffness prediction procedures are Pfeiffer's and van Doormaal's PI procedure (Pfeiffer and van Doormaal 1936) and McLeod's PVN procedure (McLeod 1976). They are based on penetration measurements or on viscosity values at high temperatures such as 135 deg C or 60 deg C.

Asphalt modifiers have also been tested for their ability to modify the low-temperature properties of asphalt cements. At high temperatures, sulfur-asphalt mixtures can increase the stiffness of a soft asphalt (300 to 400 penetration) to that of mixture made with 40-50 penetrations. The addition of sulfur has no effect on stiffness at low temperatures. Asphalt mixtures reinforced with polypropylene fibers resulted in mixtures with improved elongation capability, better resistance to freezing and thawing, and a more durable and longer-lasting service life, particularly in cold climate regions. Laboratory tests indicated that the addition of carbon black pellets to asphalt cements increased asphalt durability by increasing the viscosity at 60 deg C and by increasing the penetration at 5 deg C, a demonstration of improved low temperature susceptibility.

FAA Study

Janoo (1990) reported a study on the use of low-viscosity asphalts in airfields and highway pavements in cold regions. The report included a brief literature review on low-temperature cracking, a description of the U.S. Army Corps of Engineers specifications, and the results of a field study concerning the use of soft grade asphalts by state and Federal agencies.

Low-temperature transverse cracking occurs when the temperature-induced tensile stress in the asphalt concrete exceeds the tensile strength of the asphalt concrete. The crack begins at the asphalt concrete surface and progresses downward through the asphalt concrete layer. The bearing capacity of the pavement system reduces over time as the number of cracks increase, the size of the cracks increase, and with entry of water into the pavement cracks. During the winter months, deicing solutions can enter the cracks and cause localized thawing of the base and subbase and water entering these cracks can cause differential frost heave.

Low viscosity asphalt cements are currently recommended as binders in cold regions to reduce the potential for low-temperature cracking. The U.S. Army Corps of Engineers currently uses the penetration viscosity number (PVN) to quantify temperature susceptibility of an asphalt cement and estimate its ability to prevent low-temperature cracking (ETL 1110-1-139 1990). For road and airfield pavements, the U.S. Army Corps of Engineers specifies "standard grade" asphalts with a minimum PVN of -0.5 in the moderately cold regions and "special grade" asphalts with a minimum PVN of -0.2 in the very cold regions (Interior Alaska and Greenland).

Eighteen out of the 27 states surveyed considered low-temperature cracking to be a serious problem. Sixteen states have some form of specification for minimizing low-temperature cracking. Most states in the northern U. S. agree that low-viscosity asphalts should be used for controlling low-temperature cracking.

Janoo concluded that the propagation of low-temperature cracking is a function of the asphalt cement and the asphalt concrete properties. The following recommendations were made:

a. The behavior of asphalt concrete mixtures at low temperatures is based on data gained from asphalt concrete properties at higher temperatures. Research on characterizing the behavior of asphalt concrete mixtures at low temperatures should be developed.

b. Research on introducing additives to the asphalt cement or the asphalt cement mixture to minimize low-temperature cracking should be conducted.

c. Field techniques for controlling low-temperature cracking should be studied.

The U.S. Army Engineer Waterways Experiment Station (WES) conducted a FAA sponsored field survey of 131 airports to determine the current usage of asphalt modifiers in airfield pavement systems. It was found that the most prominent reason for using asphalt modifiers in U.S. airport pavements is to prevent or deter thermal cracking in the asphalt concrete (Anderton and Lewandowski 1992). The WES study supports Janoo's conclusion that low-temperature cracking in airport asphalt pavements should be a major concern for the FAA.

SHRP Study

The Strategic Highway Research Program reported a summary on low-temperature and thermal fatigue cracking of asphalt concrete pavements (Vinson, et al 1989). An extensive literature review was conducted that described the causes and problems associated with low-temperature cracking. Test methods that are currently used to predict low-temperature and thermal fatigue cracking in asphalt concrete mixtures were identified and reported. A test program was recommended to support the evaluation of several test methods for standardization and for use in mechanistic models.

In new pavements, cracks generally appear at 100+ ft spacings. As the pavement ages and cold temperature cycles increase, the crack spacing decreases to less than 20 ft. Factors that influence the amount of low-temperature cracking in asphalt pavements include material factors, environmental factors, and pavement structure geometry factors. The single most important material factor that influences the amount and degree of low-temperature cracking is the temperature-stiffness relationship of the asphalt cement. A high penetration/low viscosity asphalt cement is less temperature susceptible due to its lower stiffness at low temperatures. In addition, aggregates that have high abrasion resistance, high freeze-thaw resistance, and low absorption give maximum resistance to transverse cracking. The asphalt concrete mixture's aggregate gradation, asphalt cement content, and air voids content do not significantly influence the temperature susceptibility of the mix. Environmental factors that influence the amount of low-temperature cracking are pavement surface temperature, rate of cooling, and pavement age (the probability of extreme low temperature occurrence increases with time). In respect to pavement structure geometry, field evidence shows that low temperature crack spacing is closer for narrow pavements than for wider pavements. In addition, increasing the thickness of the asphalt concrete layers decreases the incidence of low-temperature cracking and increasing the friction coefficient between the asphalt layer and the base course reduces the incidence of low-temperature cracking. Low-temperature cracking is also greater for pavements on sand subgrades than on cohesive subgrades.

Numerous research studies have examined the thermal properties of asphalt concrete mix properties in relation to low-temperature cracking. SHRP recommended four test methods for further examination in a laboratory test program. These methods were:

a. Direct tension-constant rate of extension test.

b. Thermal stress restrained specimen test.

c. **Energy release rate (C*) line integral test.**

d. Coefficient of thermal expansion and contraction test.

SHRP also recommended a laboratory test program that would properly evaluate the suitability of these four methods for standardization and their ability to provide input parameters to mechanistic models for low-temperature cracking.

USAF-WES Study

WES conducted a research study on the use of alternate/modified binders for asphalt airfield pavements. One of the more prominent conclusions of the study was that styrene-butadiene-styrene (SBS) and low-density polyethylene modifiers can moderately increase the resistance to rutting and provide a substantial decrease in the binder's temperature susceptibility (Anderton, 1990). As an indirect result of this study, a modified asphalt test section will be constructed at the Thule Greenland Airbase in 1994, with trial sections consisting of a SBS and a low-density polyethylene modified asphalt sections placed in line with an unmodified control section on a main taxiway. The results of the test section evaluations should provide some insight into the effectiveness of these asphalt modifiers in deterring low-temperature cracking.

3 Site Inspections

This field evaluation was conducted to determine the performance and effectiveness of special graded (arctic grade) asphalt cements in airfield pavements that are subjected to extreme cold weather which produces severe thermal cracking. The basis of this investigation was to compare asphalt cements specified to meet PVN requirements to standard grade asphalt cements in either overlay construction, new construction, or full depth repair. Three locations, Wainwright Army Airfield, Elmendorf AFB, and Sondrestrom Air Base, were selected for site inspection and material evaluation (Figure 2). These airfield pavements contained a wide range of pavement types, asphalt cements, and construction methods. At each site, a visual inspection was conducted by the principal investigator and a pavement condition survey was conducted by a team from WES or Tyndall AFB. The details of each inspection are discussed in the following paragraphs.

Wainwright Army Airfield

Wainwright Army Airfield (WAAF) is located east of Fairbanks, Alaska, and is approximately 120 miles south of the Arctic Circle. The pavements at WAAF were originally constructed during the 1940's and 1950's. During the early 1980's, the primary pavements (North Runway, South and North Taxiways, Taxiways 1, 3, 4, and 5) were resurfaced or reconstructed. A layout of the pavement facilities at WAAF is shown in Figure 3. The pavements inspected and sampled (Items 1-7) are listed and described in Table 1.

In July 1988, a site visit was conducted by the principal investigator to inspect the airfield pavements to determine the present surface condition and to select sample locations. This visual inspection emphasized thermal cracking pavement distresses. The crack spacing and widths were determined and a subjective rating of the overall surface condition was made. During August 1989, a WES evaluation team conducted a pavement condition survey of WAAF (Harrison 1990). The Pavement Condition Index (PCI) results for this inspection are listed in Table 2.

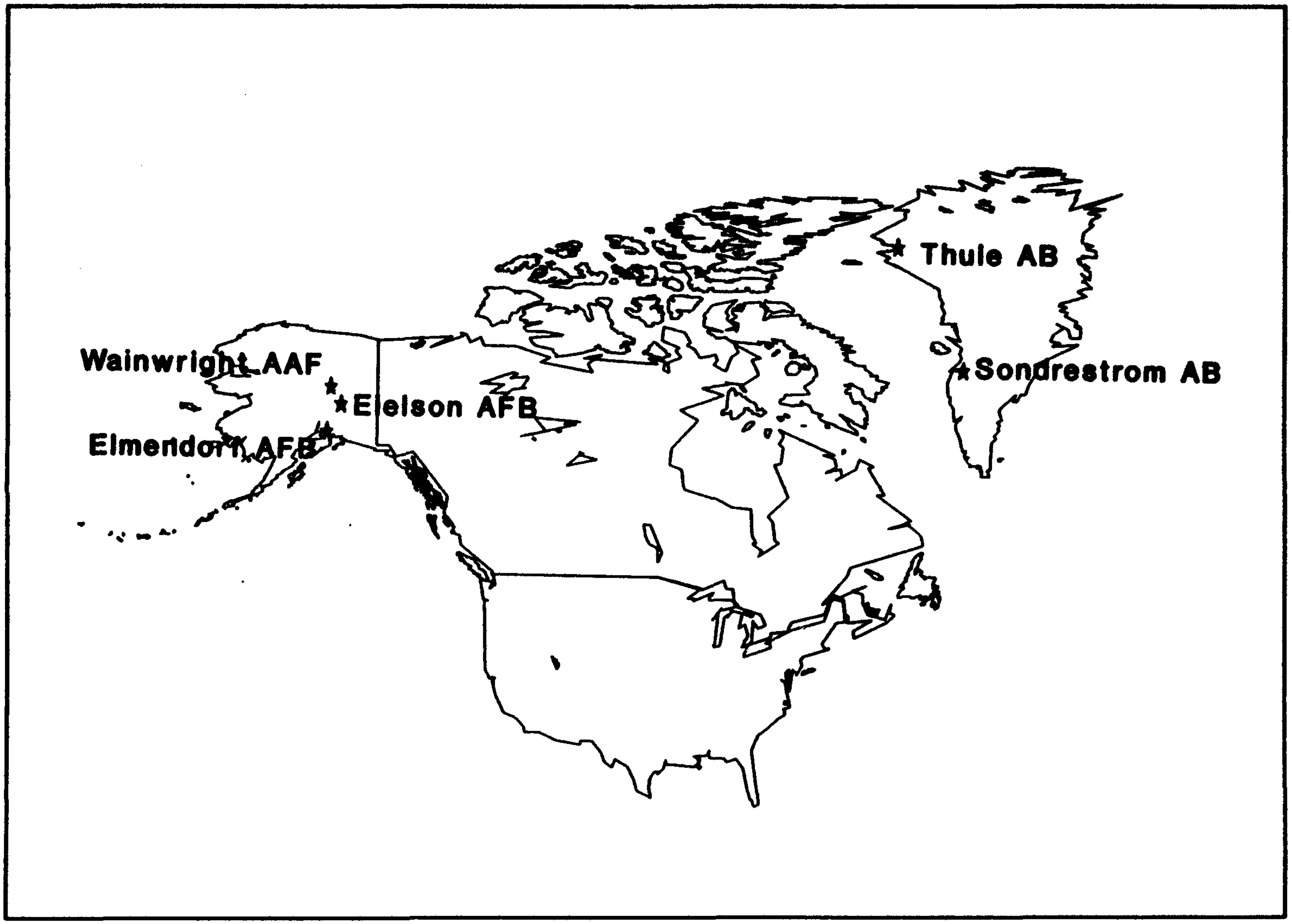


Figure 2. Locations of cold weather airfield pavements

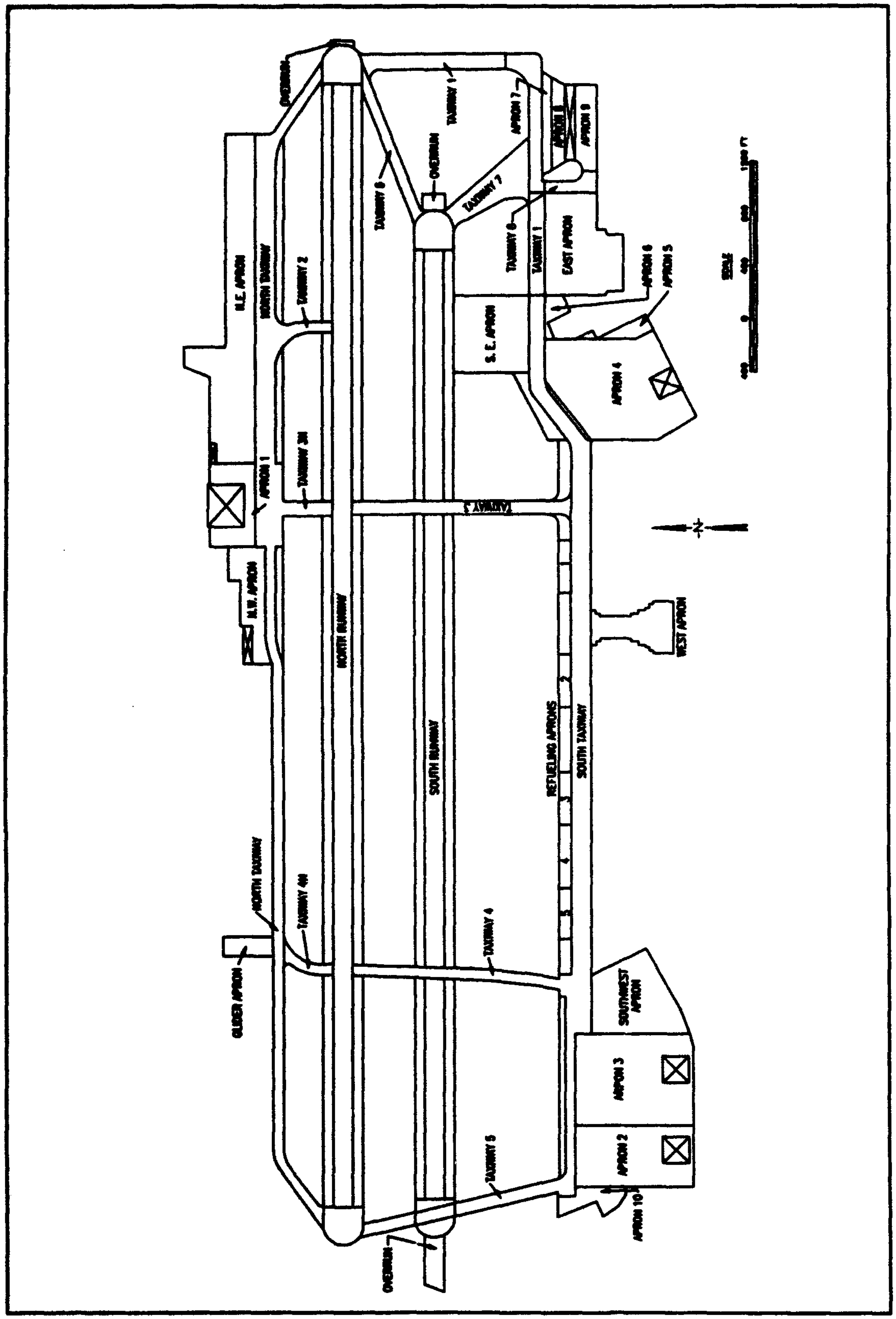


Figure 3. Layout of airfield pavements at WAAF

Table 1
Description of Pavement Items Evaluated at Wainwright Army Airfield

Item	Location	Construction Year	Pavement Age at Inspection (year)	Asphalt Type	Description
1	North Runway	1982	6	AC 5	Asphalt overlay on cracked and seated PCC
2	North Runway	1982	6	AC 5	Asphalt overlay on existing asphalt concrete
3	Taxiway 1 N/S	1983	5	AC 2.5 arctic grade	Full depth reconstruction
4	Taxiway 1 E/W	1984	4	AC 5 arctic grade	Asphalt overlay
5	Taxiway 3	1983	5	AC 2.5 arctic grade	Full depth reconstruction
6	South Taxiway	1983	5	AC 2.5 arctic grade	Full depth reconstruction
7	South Taxiway	1983	5	AC 2.5 arctic grade	Asphalt overlay

Table 2
Pavement Condition Survey Results (Harrison 1990)

Item	1984 PCI	1984 PCI Rating	1989 PCI	1989 PCI Rating	Decrease in PCI
1	80	Very good	77	Very good	3
2	80	Very good	78	Very good	2
3	100	Excellent	95	Excellent	5
4	100	Excellent	79	Very good	21
5	100	Excellent	90	Excellent	10
6	93	Excellent	83	Very good	10
7	90	Excellent	79	Very good	11

Item 1

Item 1 is located in the center portion of the North Runway and is an asphalt overlay (4 in.) placed over a cracked and seated PCC pavement (6 in.). The asphalt cement used in this asphalt overlay was a standard grade AC 5. The surface condition of this pavement was good to very good. The transverse cracks in this pavement item were spaced 60 to 80 ft apart with crack widths less than 1/2 in. The longitudinal construction joints had opened, but were sealed. Some transverse cracks in the asphalt overlay extended into the shoulder and were caused by "earth" or "ground" cracks. These soil cracks occur under intense cold conditions due to temperature induced volumetric changes. A typical transverse crack in Item 1 is shown in Figure 4.

The WES evaluation team rated this pavement item very good with an average PCI rating of 77. The major type of pavement distress was low to medium severity transverse and longitudinal cracks. The PCI rating had only decreased 3 points since the last evaluation in 1984.

Item 2

Item 2 is located at the west end of the North Runway and was overlaid in 1982 with 4 in. of asphalt concrete using standard grade AC 5. The surface condition of this pavement was also good to very good, but it was evident that this item contained more random cracking than Item 1. The transverse cracks were approximately 1/2 to 3/4 in. wide and spaced 30 to 50 ft apart. Some of these cracks were reflected and not thermally induced. Typical cracks in Item 2 are shown in Figure 5.

The WES evaluation team rated this pavement item very good with a PCI rating of 78. This same item had received a PCI rating of 80 in 1984.

Item 3

Item 3 is located in Taxiway 1 N/S at the east end of the airfield. The pavement was reconstructed in 1983 and had a total pavement thickness of 30 in. The wearing surface was 4 in. of asphalt concrete produced with arctic grade AC 2.5. The surface condition of this pavement was excellent. There was only one transverse crack (1/8 in. wide) in this 1,000 ft section (Figure 6).

The WES evaluation team rating this pavement excellent with a PCI rating of 95. The only pavement distress was low severity transverse cracking. This pavement item had been rated excellent with a PCI rating of 100 in 1984.

Item 4

Item 4 is located in Taxiway 1 E/W adjacent to the southeast apron. This pavement was overlaid in 1984 with 4 in. of asphalt concrete using arctic grade AC 5. The surface condition of this pavement was good to very good. The transverse cracks in this item were spaced 100 to 120 ft apart and were approximately 1/2 in. wide. This pavement also contained small hairline cracks spaced every 50 to 60 ft. A typical crack in Item 4 is shown in Figure 7.

The WES evaluation team rated this pavement very good with a PCI rating of 79. This pavement did have the greatest decrease in PCI ratings than any other pavement inspected. The PCI rating decreased from 100 in 1984 to 79 in 1989. It was evident that the asphalt overlay with AC 5 (Item 4) was not performing as well as the reconstructed section with AC 2.5 (Item 3).

Item 5

Item 5 is located in Taxiway 3 which serves as a connecting taxiway between the South Aprons and the North Runway. This pavement section was reconstructed in 1983 and had a total pavement thickness of 38 in. The wearing surface was 4 in. of asphalt concrete produced with arctic grade AC 2.5. The surface condition of this pavement was very good. The transverse cracks were spaced every 100 to 200 ft with some as far as 250 ft apart. The typical crack width was 1/2 in.

The WES evaluation team rated this pavement excellent with a PCI rating of 90. The only pavement distress noted was transverse and longitudinal cracking at low and medium severities.

Item 6

Item 6 is located in the South Taxiway between the West and Southwest aprons. This pavement section was reconstructed in 1983 and had a total pavement thickness of 38 in. The wearing surface was 4 in. of asphalt concrete produced with arctic grade AC 2.5. The surface of this pavement was rated fair to very good. The transverse cracks were spaced 60 to 180 ft apart and the cracks were approximately 1/2 in. wide. The majority of the transverse cracks were low to medium severity. This pavement section also contained some high severity cracks (earth cracks) that were over 1 in. wide and 6 to 7 in. deep (Figure 8).

The WES evaluation team rated this pavement very good with a PCI rating of 83. The primary pavement distress in this pavement was low to high severity transverse and longitudinal cracking. The PCI rating had decreased 10 points since the last evaluation in 1984.

Item 7

Item 7 is located in the South Taxiway near Apron 3. This pavement was overlaid in 1983 with 4 in. of asphalt concrete using arctic grade AC 2.5. The surface condition of this pavement was good to very good. The transverse cracking was similar to the other pavement items with crack spacing 60 to 120 ft apart. The typical crack width was 1/2 in.

The WES evaluation team rated this pavement very good with a PCI rating of 79. The PCI rating had decreased 11 points in 5 years. The primary pavement distress was noted to be low to high severity transverse and longitudinal cracking.

Figure 4. Typical transverse crack in Item 1 (North Runway)

Figure 5. Typical transverse cracks in Item 2 (North Runway)

Figure 6. Single transverse crack in Item 3 (Taxiway 1 N/S)

Figure 7. Typical transverse crack in Item 4 (Taxiway 1 E/W)

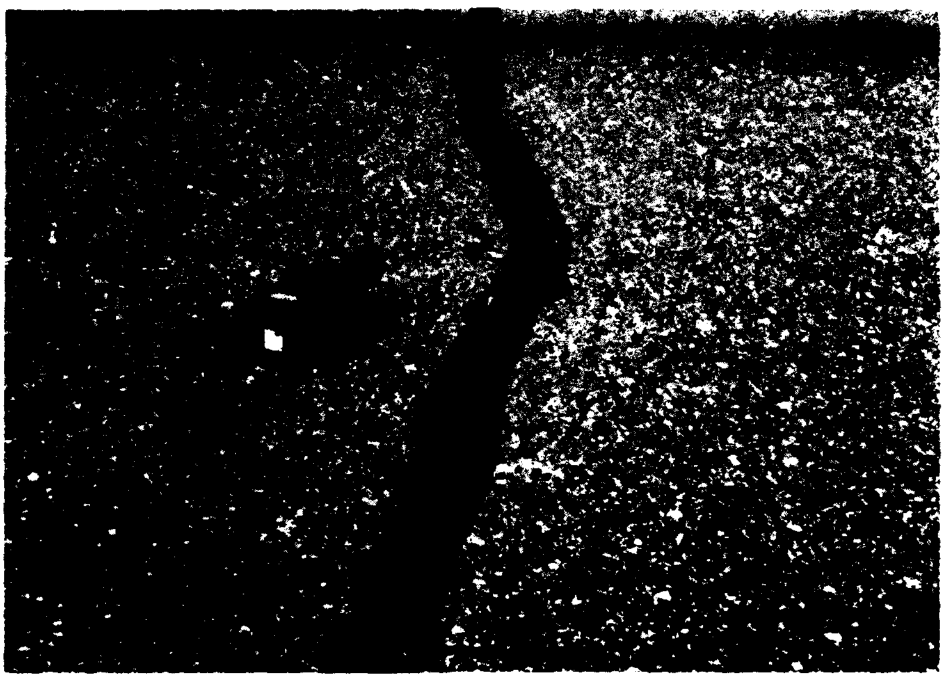


Figure 8. High severity transverse crack in Item 6 (South Taxiway)

Elmendorf Air Force Base

Elmendorf AFB is located north of Anchorage, Alaska, and is approximately 375 miles south of the Arctic Circle. The pavements at Elmendorf AFB were originally constructed during the 1940's and 1950's. During the late 1970's and early 1980's, the runways and parking aprons were resurfaced or reconstructed. A layout of the pavement facilities at Elmendorf AFB is shown in Figure 9. The pavements inspected and sampled (Items 1-3) are listed and described in Table 3.

Table 3
Description of Pavement Items Evaluated at Elmendorf AFB

Item	Location	Construction Year	Pavement Age at Inspection (years)	Asphalt Type	Description
1	East-west apron	1985	3	AC 5 arctic grade	Full depth reconstruction and asphalt overlay
2	North-south apron	1981	7	AC 5	Full depth reconstruction
3	East-west runway	1978	10	AC 2.5	Asphalt overlay

In July 1988, a site visit was conducted by the principal investigator to determine the current surface condition of the airfield pavements and to select sample locations. This visual inspection emphasized thermal cracking pavement distresses. The crack spacing and crack widths were determined and a subjective rating of the overall surface condition was made. During August and September of 1989, a pavement evaluation team from Tyndall AFB conducted a nondestructive airfield evaluation that included a visual survey of each pavement feature (Buncher et al 1990). This evaluation was a qualitative assessment of the surface conditions and was based on random counts of major distresses.

Item 1

Item 1 is located in the East-West apron adjacent to the PCC parking apron. The asphalt pavements in this apron were either an asphalt overlay or a full depth reconstruction. The 20 ft of asphalt pavement adjacent to the PCC slabs were reconstructed in 1985 and surfaced with 3 in. of asphalt concrete produced with arctic grade AC 5. The remaining apron pavement was overlaid that year with the same asphalt concrete. The surface condition of this pavement was good to excellent. The reconstructed section contained no cracks and was in excellent condition. The section of Item 1 that was an

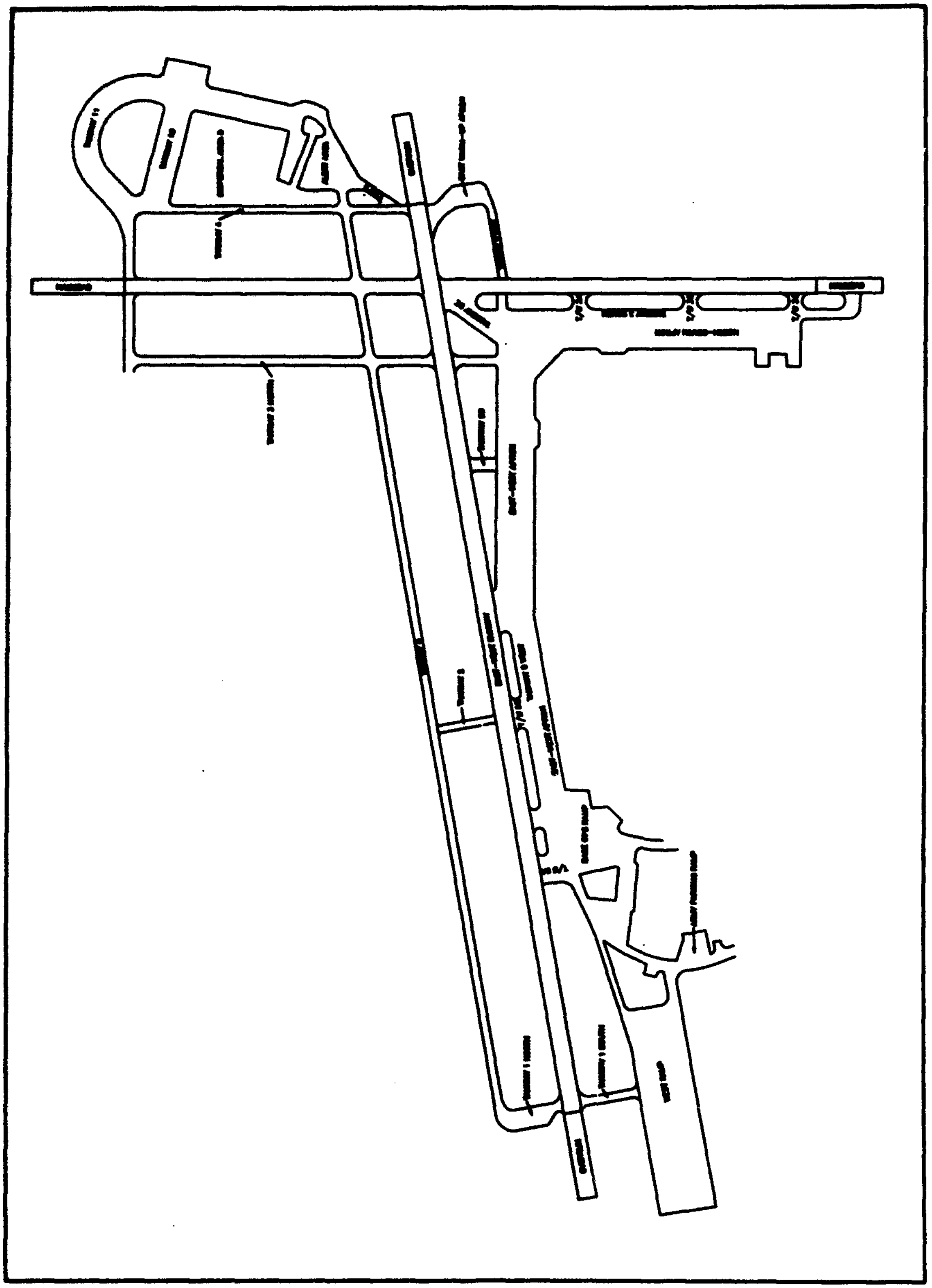


Figure 9. Layout of airfield pavements at Elmendorf AFB

asphalt overlay contained transverse cracks that occurred every 40 ft and longitudinal cracks that occurred on the construction joints. These transverse cracks were approximately 1/2 to 3/4 in. wide and appeared to be reflected from the underlying PCC pavement (Figure 10). Typical pavement conditions for the asphalt overlay and full depth reconstruction are shown in Figures 10 through 12.

The Air Force pavement evaluation team rated this pavement item very good to excellent. The asphalt surface adjacent to the PCC slabs was rated excellent while the remaining asphalt overlay was rated very good. The primary pavement distress was low to medium severity transverse and longitudinal cracking.

Item 2

Item 2 is located in the North-South Apron adjacent to the F15 PCC parking apron. The asphalt pavement was reconstructed in 1981 with a pavement consisting of a 6 in. base and a 3 in. wearing surface. The asphalt wearing surface was produced with standard grade AC 5. The surface condition of this pavement was good to very good. The transverse cracks were spaced 60 ft apart and were 1/2 in. wide. A typical crack in Item 2 is shown in Figure 13.

The Air Force evaluation team rated this pavement good to very good. The primary distresses were shrinkage (thermal) cracks and longitudinal cracks at the construction joints. Alligator cracks were noted along the AC/PCC interface and were determined to be caused by a loss of base support.

Item 3

Item 3 is located in the center portion of the East-West Runway and was overlaid in 1978 with an asphalt concrete overlay (3 in.) using AC 2.5. The surface condition of this pavement was very good to excellent. The transverse cracks were spaced 60 ft apart and were 1/4 to 1/2 in. wide. The longitudinal construction joints had opened to approximately 1/2 in. This pavement section did not have any random cracks which was considered a remarkable condition after 10 years of extreme cold weather. A typical transverse crack across the east-west runway is shown in Figure 14.

The Air Force evaluation team rated this pavement very good in 1989. The major distresses were longitudinal construction joints and transverse shrinkage cracks.

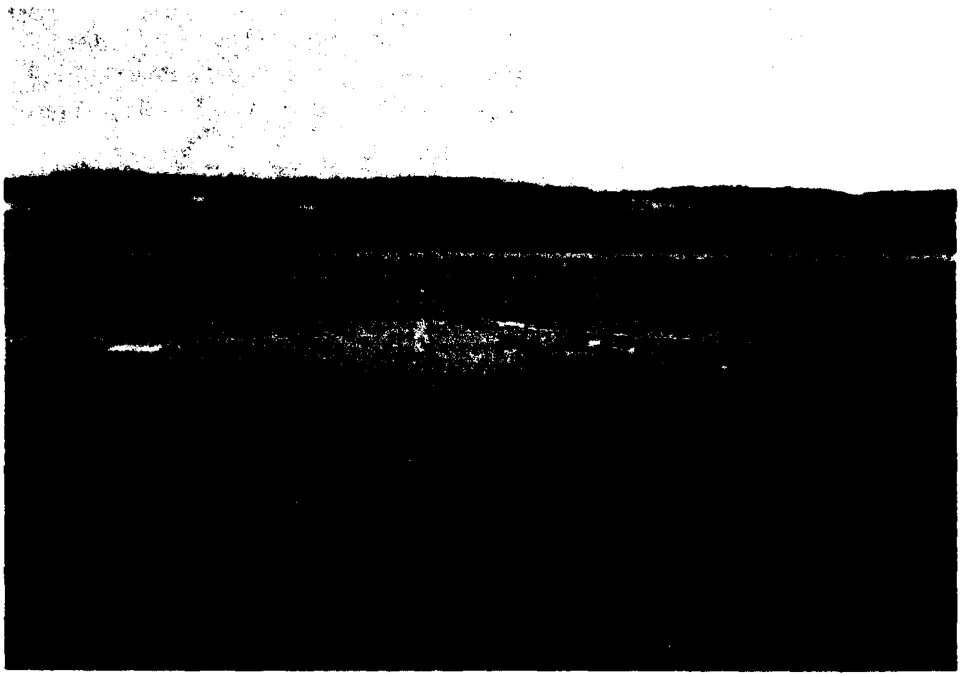


Figure 10. Transverse crack reflected from underlying pavement (Item 1)

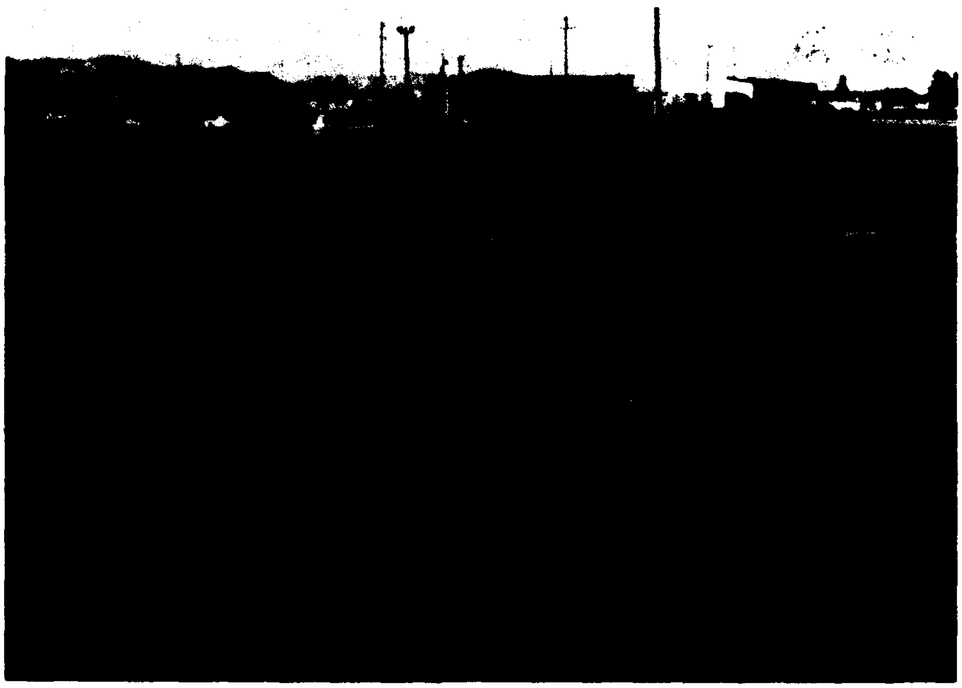


Figure 11. Typical transverse crack in asphalt overlay section in Item 1

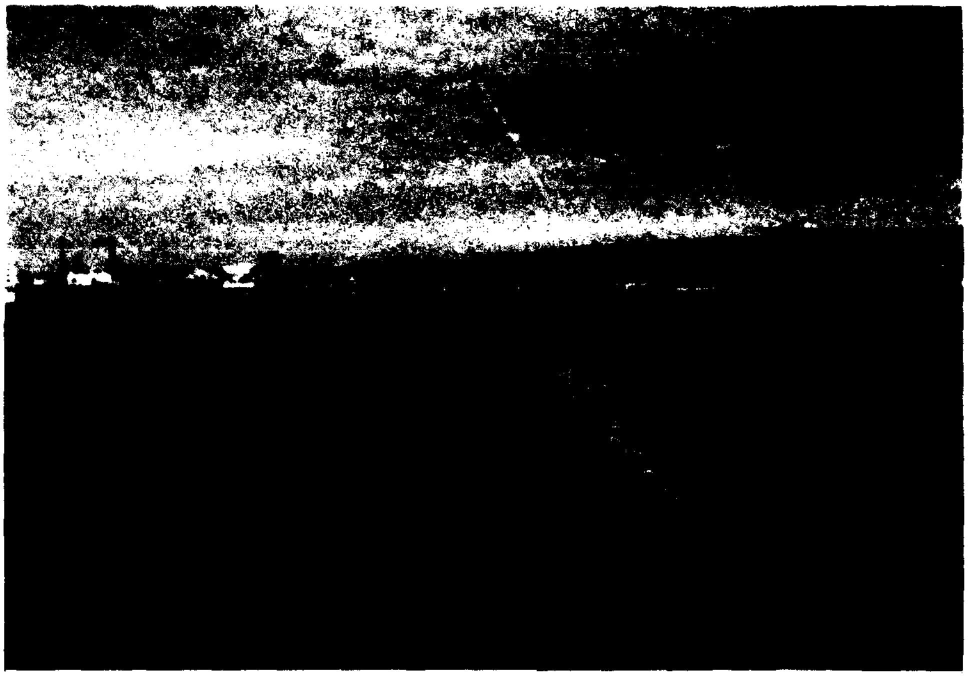


Figure 12. No cracks in reconstructed section of Item 1

Figure 13. Typical longitudinal crack in Item 2

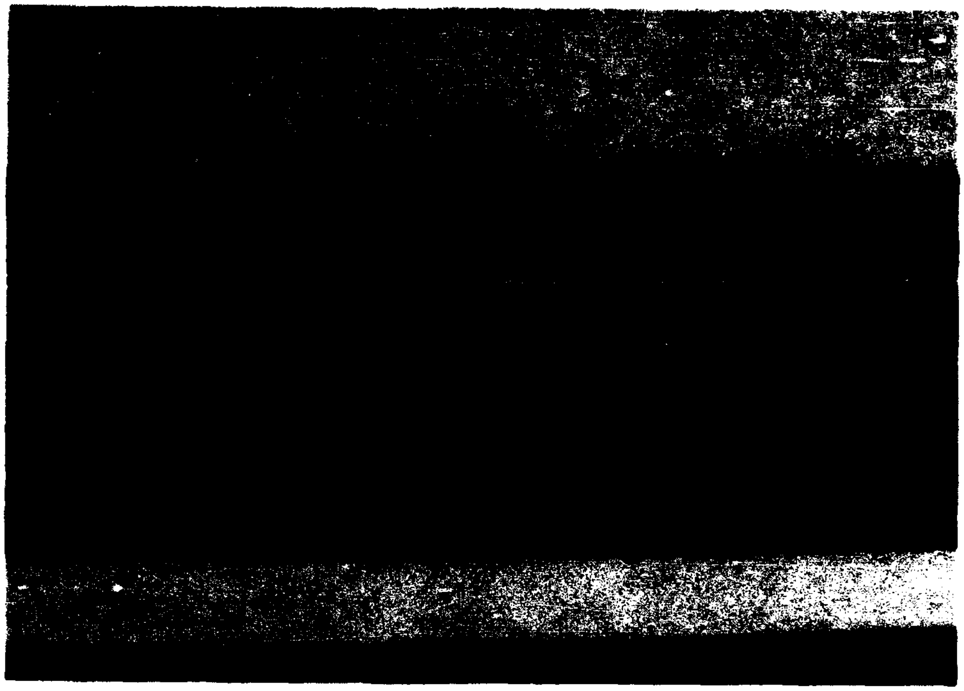


Figure 14. Typical transverse crack in Item 3

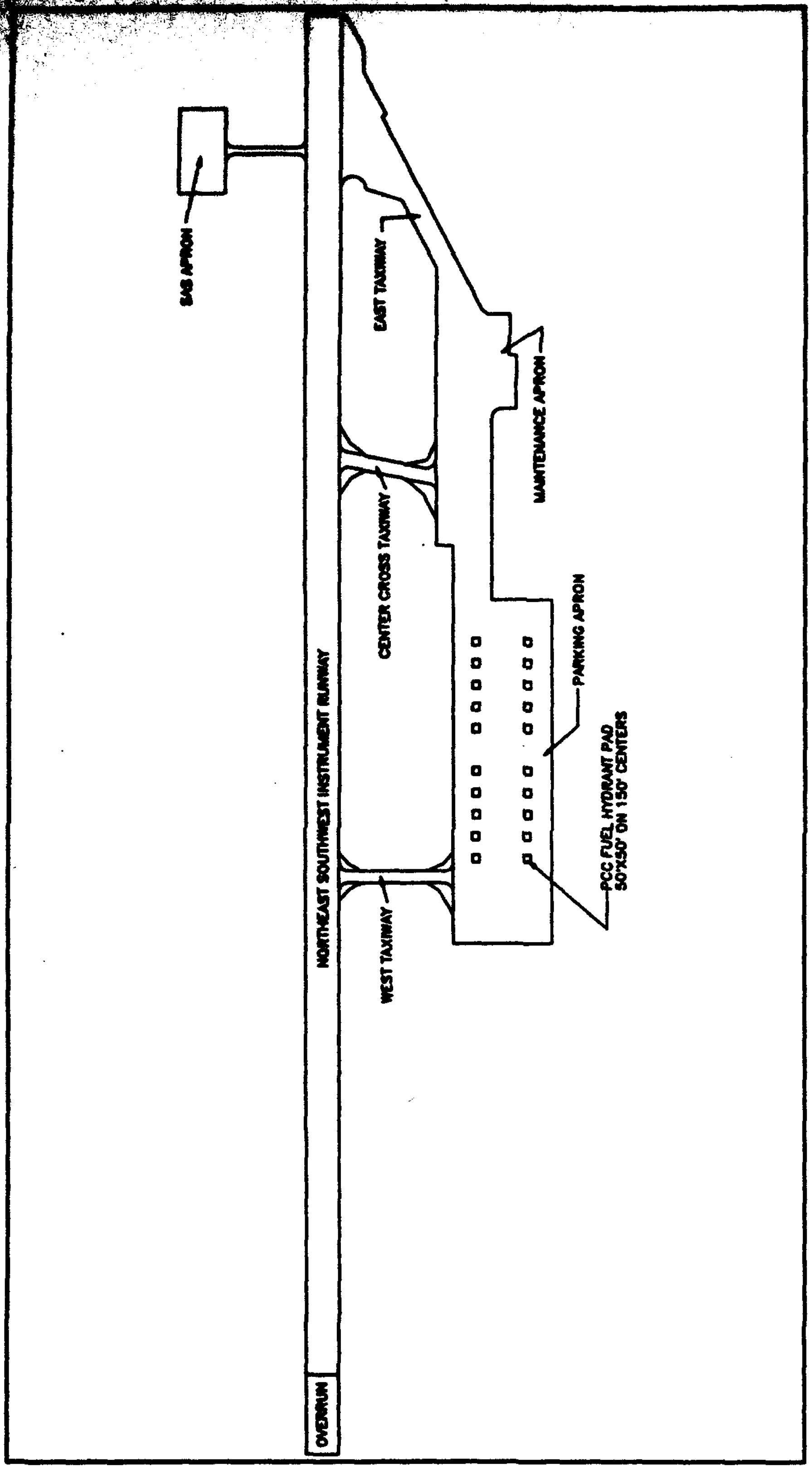


Figure 15. Layout of airfield pavements at Sondrestrom Air Base

Sondrestrom Air Base

Sondrestrom Air Base is located on the southwest coast of Greenland approximately 80 miles north of the Arctic Circle. Sondrestrom AB is surrounded by two ice caps, the Greenland Ice Cap and the Sukkertopper Ice Arm. The cold weather in Sondrestrom AB is extremely harsh on the airfield pavements. The airfield pavements at Sondrestrom AB were originally constructed in 1942 and were expanded during the 1950's. From 1985 to 1988 all the primary pavements were resurfaced or reconstructed. A layout of the pavement facilities at Sondrestrom AB is shown in Figure 15. The pavements inspected and sampled (Items 1-3) are listed and described in Table 4.

In June 1988, a site visit was conducted by the principal investigator to inspect the airfield pavements to determine the current surface condition and to select sample locations. This visual inspection emphasized thermal cracking pavement distresses. One year later (1989), a pavement evaluation team from Tyndall AFB conducted a nondestructive pavement evaluation for each pavement feature (Millard et al 1989).

Table 4
Description of Pavement Items Evaluated at Sondrestrom AFB

Item	Location	Construction Year	Pavement Age at Inspection (years)	Asphalt Type	Description
1	Runway west end	1985	3	AC 2.5 arctic grade	Full depth reconstruction
2	Runway interior	1986	2	AC 2.5 arctic grade	Asphalt overlay
3	East Taxiway/ Maintenance Apron	1987	1	AC 2.5 arctic grade	Full depth reconstruction/ asphalt overlay

Item 1

Item 1 is located at the west end of Runway 11-29. This pavement was reconstructed in 1985 with a total pavement thickness of 24 in. This flexible pavement included 6 in. of nonfrost susceptible (NFS) base course and 4 to 6 in. of asphalt concrete produced with arctic grade AC 2.5. The surface condition of this pavement was good to very good. The only pavement distress in this item was transverse cracking and longitudinal construction joints opening. The transverse cracks were spaced 75 to 100 ft apart and were 1/2 in. wide. There were some random cracks (1/4 in. wide) that had developed between the transverse cracks and were the first signs of block cracking. A typical longitudinal crack is shown in Figure 16.

The Air Force evaluation team rated this pavement very good in 1989. The major pavement distress was noted to be transverse and longitudinal cracking caused by thermal shrinkage of the asphalt pavement.

Item 2

Item 2 is located in the interior of Runway 11-29 and was overlaid in 1986 with 3 to 6 in. of asphalt concrete produced with the same arctic grade AC 2.5. Prior to the asphalt overlay, extensive crack repair and crack sealing was performed. The surface condition at the time of inspection was good. It was evident that all of the repaired cracks had reflected through the new overlay. These cracks were primarily transverse and spaced 60 to 100 ft apart and 1/2 to 1 in. wide. A typical crack from the interior of the runway is shown in Figure 17.

The Air Force evaluation team also rated this section good and noted that the predominant distress was transverse and longitudinal cracks. The severity of these cracks varied from low to high.

Item 3

Item 3 is located in portions of the East Taxiway and the Maintenance Apron. The asphalt pavements in this item were constructed in 1987 as either an asphalt overlay (East Taxiway) or full depth reconstruction (Maintenance Apron). The full depth reconstruction included a non-frost susceptible (NFS) base course and 6 to 9 in. of asphalt concrete produced with arctic grade AC 2.5. The asphalt overlay (3 to 6 in.) on the east taxiway was constructed during the same summer using the same asphalt concrete material. The surface condition of the full depth reconstruction area was excellent (no cracks) while the surface condition of the overlay was very good. The difference in these two pavements was reflected transverse and longitudinal cracks (1/8 in.) nominal width in the asphalt overlay section. Typical pavement conditions of this item are shown in Figures 18-19.

The Air Force pavement evaluation team also rated this pavement very good in 1989 and noted that longitudinal and transverse cracking were the primary pavement distresses.

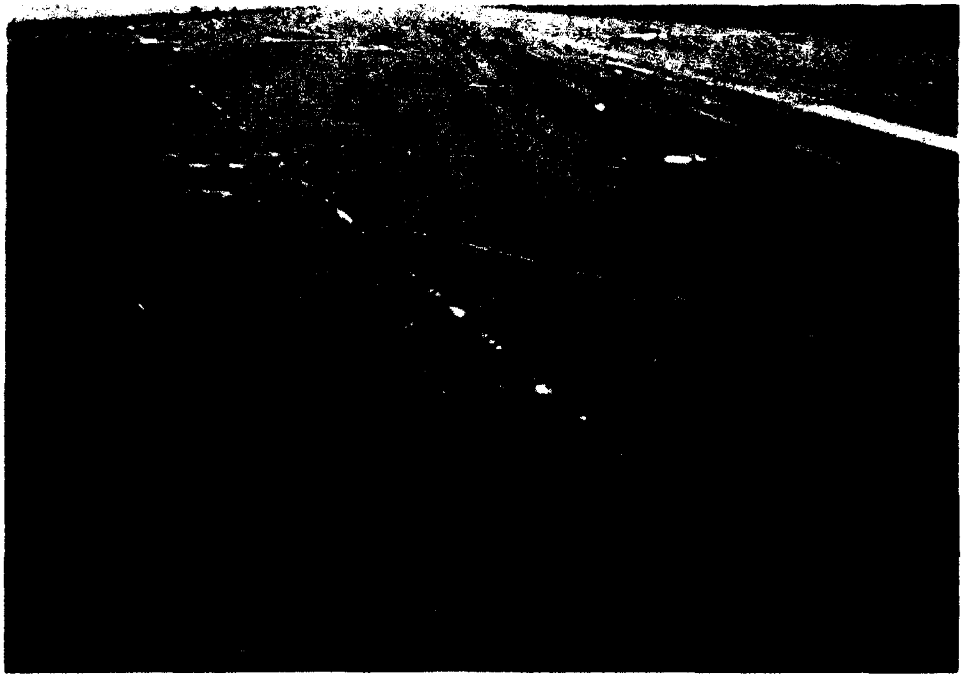


Figure 16. Typical longitudinal crack in west end of runway (Item 1)

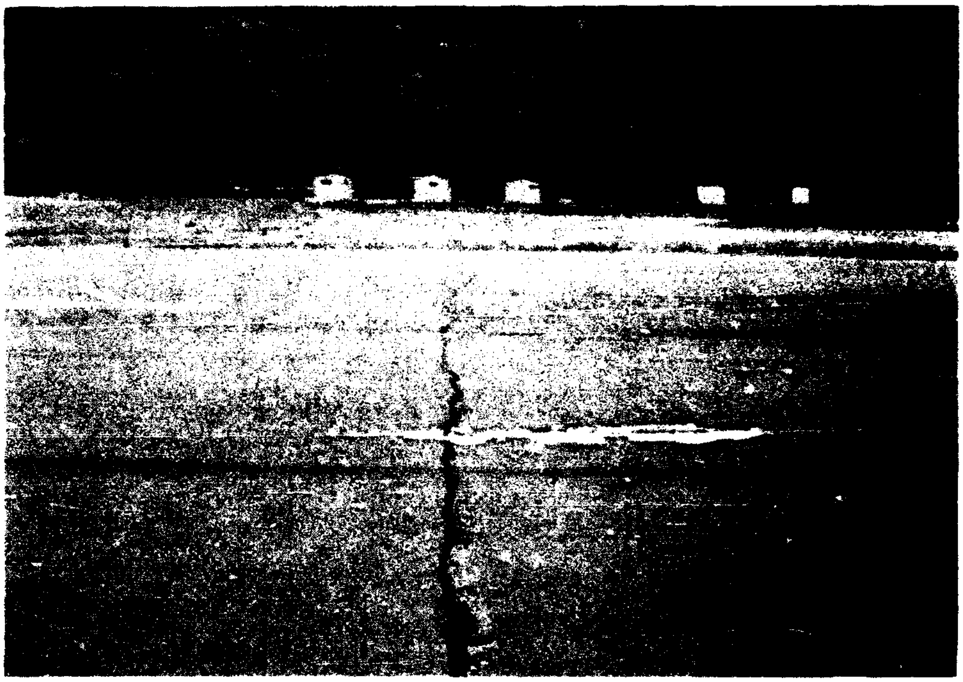


Figure 17. Typical transverse crack (reflected) in interior portion of runway (Item 2)

Figure 18. Overall view of Maintenance Apron full depth reconstruction (Item 3)

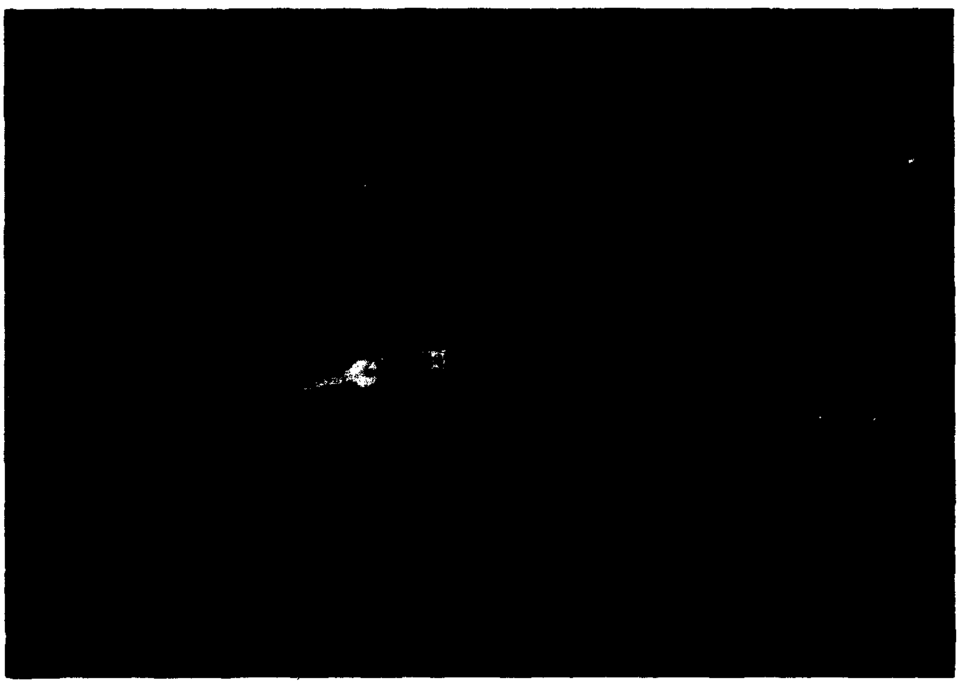


Figure 19. Close up of Maintenance Apron pavement (Item 3)

4 Materials Evaluation

Field samples (4 to 6 in. diameter cores) were taken at each airfield location from the selected pavement items so that in place material properties could be determined. The laboratory evaluation was focused on the asphalt cement and asphalt concrete properties since this study primarily concentrated on thermal stresses and cracking.

Field cores from each item were tested with the following laboratory procedures. The thickness and density of each core were determined. Then, the cores representing a particular item, always separating the surface and intermediate layers, were trimmed and combined to produce a representative asphalt mixture sample. The asphalt mixture was then extracted using test method ASTM D 2172 to separate the aggregate and asphalt cement and to determine the asphalt content. The recovered aggregates were used to determine the aggregate gradation using test methods ASTM C 117 and C 136. The asphalt cement was then recovered using the Abson recovery procedures (ASTM D 1856). The recovered asphalt cements were tested to determined the penetration (ASTM D 5), softening point (ASTM D 36), kinematic viscosity (ASTM D 2170) and absolute viscosity (ASTM D 2171).

The asphalt cement test results were used to determine the temperature susceptibility of the asphalt cement by calculating the Pen-Vis Number (PVN) and the Penetration Index (PI). PVN was calculated using the following formula:

$$PVN = (-1.5)\ \frac{(L-X)}{(L-M)}$$

where:

X = log (kinematic viscosity @ 275°F)
L = 4.25800 - 0.79674 [log (pen @ 77°F)]
M = 3.46289 - 0.61094 [log (pen @ 77°F)]

PI was calculated using the following formula:

$$PI = \frac{8.40 - 10 \log (P77/P39)}{0.42 + \log (P77/P39)}$$

where:

P77 = penetration @ 77°F
P39 = penetration @ 39°F

Wainwright Army Airfield

Six-in. field cores were taken by Alaska District personnel during August 1988 and shipped to WES for laboratory testing. A summary of the asphalt concrete mixture properties are listed in Table 5. The test results indicated that the properties of the asphalt concrete mixture were adequate for a high quality airfield pavement. The only material property that was consistently outside the recommended specifications was the minus No. 200 material. These values were above the maximum limit of 6 percent and could cause the asphalt cement to be less ductile and to stiffen.

The values of the recovered asphalt cement properties are listed in Table 6. The penetration and viscosity test results indicated that these asphalt cements had hardened and stiffened. The calculated PVN values for the recovered asphalt cements are shown in Figure 20. The PVN values are all below the minimum criteria for severe cold climates (-0.2), but the arctic grade asphalt cements for Items 3-7 do meet the PVN requirements for moderate cold climates (-0.5). There was a significant difference between PVN values when comparing standard grade asphalt cements (PVN = -1.3) to arctic grade asphalt cements (PVN = -0.4). The PI values averaged 5.8 for the standard grade asphalt cements and 6.9 for the arctic grade asphalt cements.

Table 5
Summary of Asphalt Concrete Properties - Wainwright Army Airfield

Sieve Size	Airfield Specs	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7
3/4 in.	100	100	100	100	100	100	100	100
1/2 in.	82-96	92.3	97.0	90.5	91.1	94.9	92.0	92.1
3/8 in.	75-89	87.2	91.5	80.0	83.3	85.7	85.8	85.5
No. 4	59-73	70.1	74.3	59.6	66.2	64.2	63.0	64.1
No. 8	46-60	50.8	53.6	44.2	49.3	46.9	47.9	47.9
No. 16	34-48	39.2	41.6	35.1	39.2	36.5	38.1	37.5
No. 30	24-38	32.4	34.8	29.5	33.2	30.4	32.3	31.3
No. 50	15-27	23.1	24.5	21.9	24.4	22.1	23.9	22.8
No. 100	8-18	11.7	11.8	11.1	11.5	10.7	11.6	11.5
No. 200	3-6	7.5	7.7	6.7	6.6	6.4	6.9	6.9
AC content (%)		5.8	5.8	4.7	5.0	5.0	5.0	5.1
Dust/AC ratio		1.29	1.33	1.43	1.32	1.28	1.38	1.35
Thickness (in.)		2.0	1.9	2.3	2.3	2.8	2.4	2.4
Density (pcf)		146.8	146.9	143.3	149.7	146.6	150.2	149.7

Table 6
Recovered Asphalt Cement Properties - Wainwright Army Airfield

Material Property		Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7
Penetration	39°F	25	18	47	47	48	57	49
	77°F	65	49	92	85	94	115	103
Viscosity	140°F	1426	2311	1612	2106	1856	1398	1544
	275°F	257	315	359	409	376	331	347
Softening Point (°F)		117	122	115	118	117	113	115
PVN		-1.3	-1.3	-0.5	-0.4	-0.4	-0.3	-0.4
PI		5.1	5.7	6.9	7.2	6.9	6.8	6.6

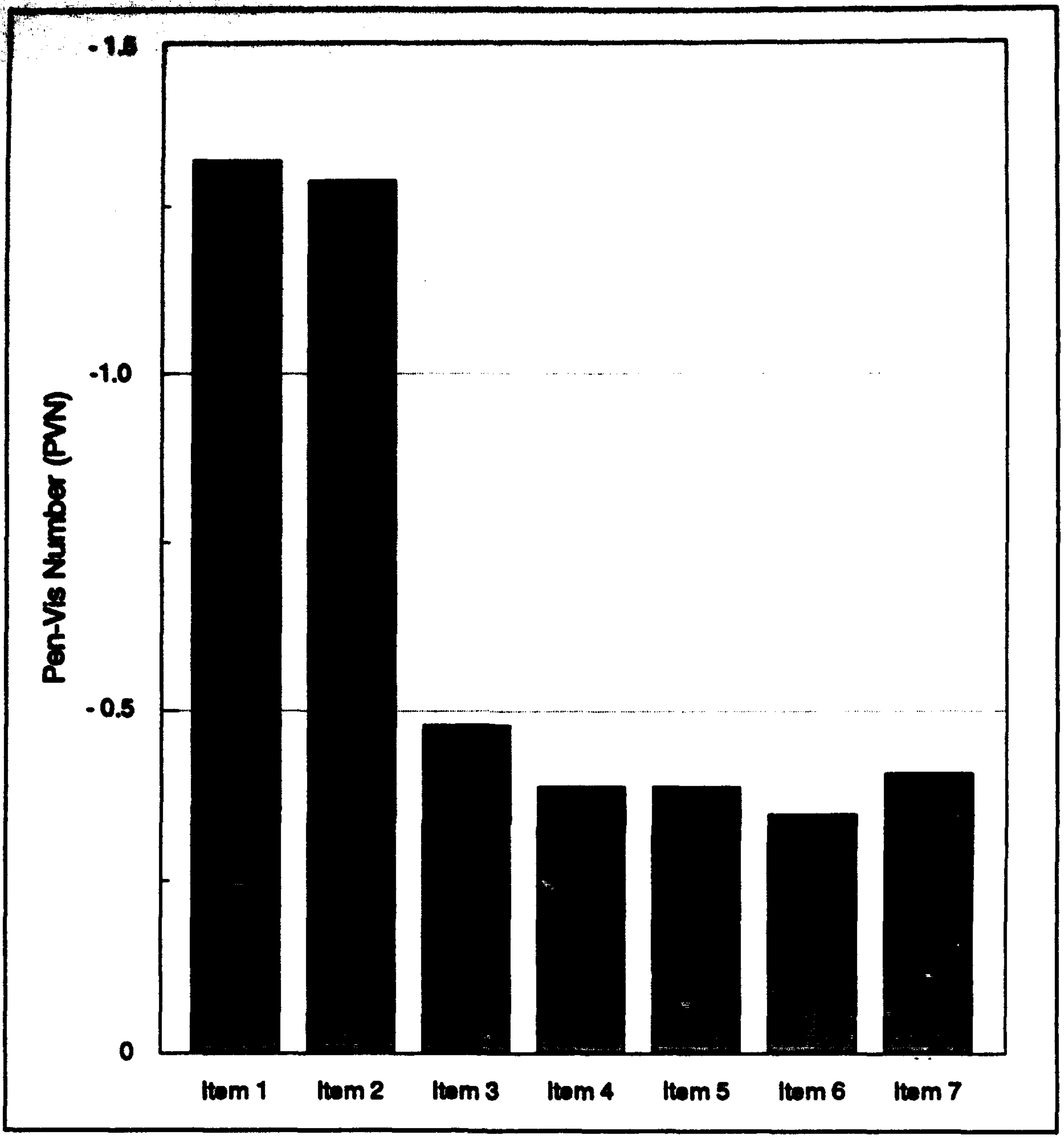


Figure 20. Pen-Vis Numbers (PVN) for asphalt cements at Wainwright Army Airfield

Elmendorf Air Force Base

Two asphalt concrete field cores (6 in. diameter) were taken in each of these items at Elmendorf AFB, AK by Alaska District personnel and shipped to WES for laboratory testing. In Items 1 and 2, the field cores were taken within 20 ft of the PCC parking apron in the full depth reconstruction area. A summary of the asphalt concrete mixture properties are listed in Table 7. The test results indicated that the asphalt concrete mixtures were adequate for airfield pavements. Again, the only aggregate property that was consistently outside the recommended specification was the minus No. 200 material. All samples had minus No. 200 material above the 6 percent limit with Item 2 containing extremely high minus No. 200 values (8.4 and 10.1 percent). These high fine contents could be detrimental to the quality of the pavement by stiffening the asphalt cement and thus increasing the potential for low-temperature cracking.

The values of the recovered asphalt cement properties and the asphalt properties of the original asphalt cement for Items 2 and 3 are listed in Table 8. The original asphalt cement property values were taken from job-mix-formula test data provided by the U.S. Amy Engineer District, Alaska. The penetration and viscosity test results indicated the asphalt cements had hardened with Item 3 having the stiffer asphalt cement material. The penetration values for the recovered asphalt cements have been reduced by 50 to 75 percent when compared to the original asphalt cement property values. The calculated PVN values for the recovered asphalt cements and the original asphalt cements are shown in Figure 21. All the PVN values are less than -0.7 and do not meet the requirements stated in ETL 1110-1-139 for cold climates. The philosophy that the PVN value does not change with age (heating, mixing, and service) is substantiated with the data from Items 2 and 3. The PI values average 6.0 for the arctic grade AC 5, 5.7 for the standard grade AC 5 and 6.5 for the AC 2.5.

Table 7
Summary of Asphalt Concrete Properties - Elmendorf AFB

Sieve Size	Airfield Specs	Item 1		Item 2		Item 3	
		Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
3/4 in.	100	100	100	100	100	100	100
1/2 in.	82-96	95.4	90.6	95.5	94.4	96.3	93.2
3/8 in.	75-89	86.7	82.4	87.1	88.3	86.0	84.2
No. 4	59-73	64.6	61.2	71.8	72.0	69.0	72.5
No. 8	46-60	49.1	47.1	60.8	58.7	52.6	54.4
No. 16	34-48	35.0	34.6	40.1	39.7	38.5	39.4
No. 30	24-38	25.6	25.9	26.9	27.9	28.8	29.0
No. 50	15-27	17.2	17.4	17.9	19.7	19.6	18.2
No. 100	8-18	10.3	10.5	12.0	13.9	11.8	10.6
No. 200	3-6	6.7	6.9	8.4	10.1	7.0	7.1
Asphalt content (%)		5.5	5.3	5.7	6.0	6.5	6.7
Dust/AC ratio		1.22	1.30	1.47	1.68	1.08	1.06
Thickness (in.)		2.5	2.0	1.8	1.8	3.0	1.5
Density (pcf)		147.9	150.4	152.2	150.9	150.1	151.0

Table 8
Recovered Asphalt Cement Properties - Elmendorf AFB

Material Property	Item 1		Item 2			Item 3			
	Sample 1	Sample 2	Original AC	Sample 1	Sample 2	Original AC 1	Original AC 2	Sample 1	Sample 2
Penetration 39°F (0.1 mm) 77°F (0.1 mm)	 22 54	 24 61	 -- 145	 25 74	 34 89	 -- 186	 -- 157	 22 45	 22 52
Viscosity 140°F (P) 275°F (cSt)	 2322 434	 2134 416	 473 172	 1083 259	 791 232	 288 135	 290 130	 2719 352	 1579 263
Softening Point (°F)	126	124	--	117	115	--	--	124	122
PVN	-0.8	-0.7	-1.2	-1.2	-1.2	-1.3	-1.5	-1.2	-1.5
PI	6.0	5.9	--	5.5	5.8	--	--	6.7	6.2

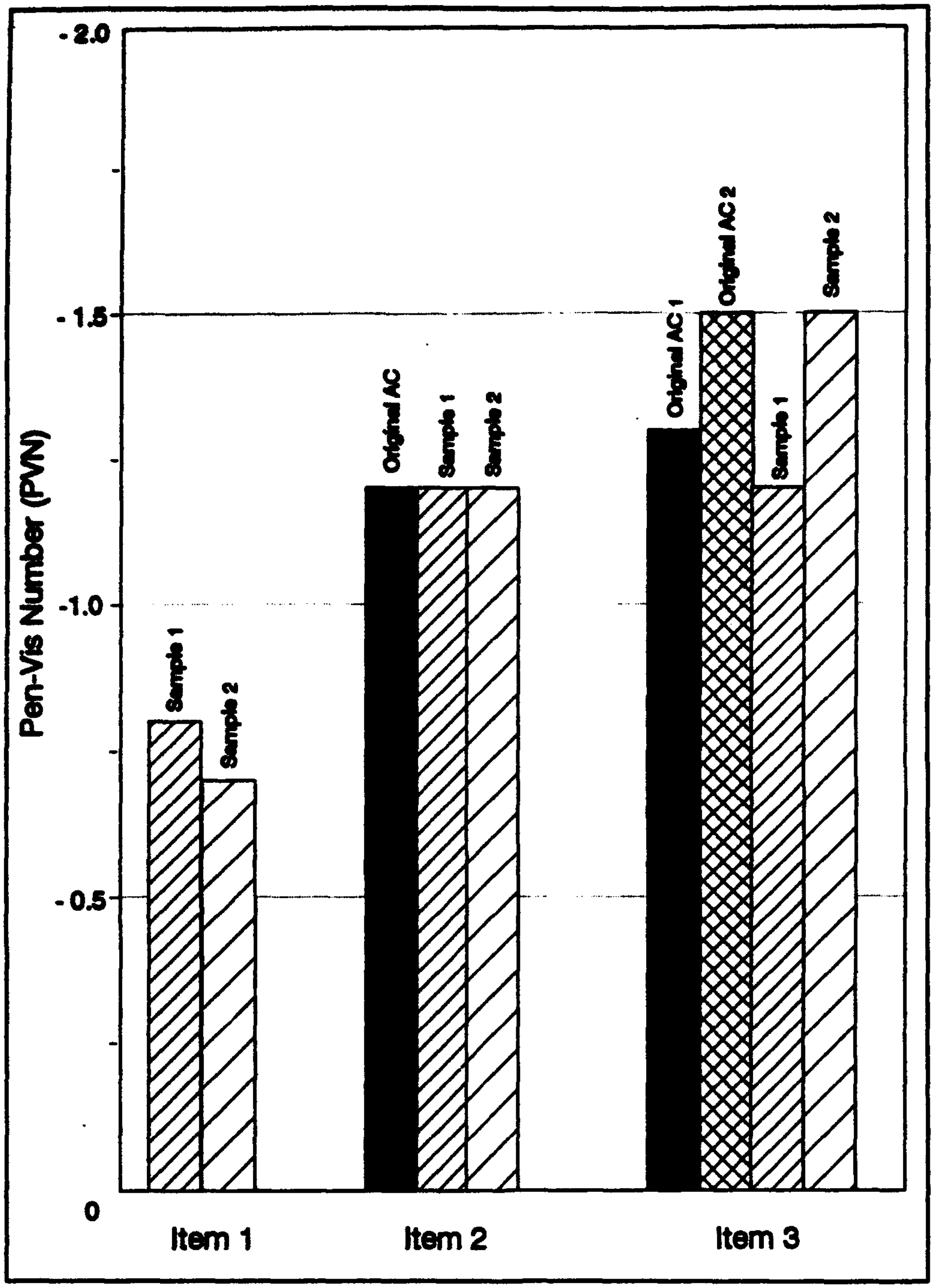


Figure 21. Pen-Vis Numbers (PVN) for asphalt cements at Elmendorf AFB

Sondrestrom Air Base

In place pavement samples were obtained by the paving contractor, Superfos, during June 1988 and shipped to WES for evaluation. Three field cores (4 in. diameter) were taken at both sample locations in Items 1 and 3. The sample locations were located in the full depth reconstruction areas of the Runway and Maintenance apron. A summary of the asphalt concrete mixture properties are listed in Table 9. The asphalt cores were separated between lifts to evaluate the intermediate and surface course layers separately. The test results indicated the properties of the asphalt concrete mixture were adequate for airfield pavements. The aggregate gradations of these field cores also indicated excessive minus No. 200 material with most values greater than 7.0 percent.

The values of the recovered asphalt cement properties and the original asphalt cement for Items 1 and 3 are listed in Table 10. The original asphalt cement property values were taken from job-mix-formula test data provided by the project contractor. The penetration and viscosity test results indicated that the asphalt cement properties had hardened and stiffened with time. The penetration values for Item 1 (3 years old) were lower than Item 3 (1 year old) and the viscosity values for Item 1 were higher than Item 3. The calculated PVN values for the recovered asphalt cements and the original asphalt cements are shown in Figure 22. The PVN values are all below the minimum criteria for severe cold climates (-0.2) and averaged -0.6. The PVN values from the recovered asphalt cements varied slightly from the original asphalt cement with the inplace materials having lower PVN values and being more temperature susceptible. The PI value averaged 6.6 for Item 1 and 6.4 for Item 3.

Table 9
Summary of Asphalt Concrete Properties - Sondrestrom Air Base

Sieve Size	Airfield Specs	Item 1				Item 3			
		Sample 1		Sample 2		Sample 1		Sample 2	
		Surface	Intermediate	Surface	Intermediate	Surface	Intermediate	Surface	Intermediate
3/4 in.	100	100	100	100	100	100	96.5	100	91.6
1/2 in.	82-96	93.7	92.2	93.4	90.3	93.4	77.0	94.3	78.5
3/8 in.	75-89	84.4	84.4	82.6	80.7	79.6	68.2	83.4	72.0
No. 4	59-73	69.6	71.9	66.9	70.1	61.4	53.5	61.8	57.2
No. 8	46-60	53.5	56.8	51.2	54.5	46.8	42.3	48.1	42.5
No. 16	34-48	39.6	42.3	38.1	39.9	37.0	34.7	38.4	32.5
No. 30	24-38	29.3	31.5	28.5	29.8	28.7	27.9	29.8	24.3
No. 50	15-27	20.1	21.4	19.8	20.6	19.1	19.2	19.0	15.4
No. 100	8-18	12.5	12.7	12.2	12.6	11.8	11.6	11.1	9.1
No. 200	3-6	7.5	7.1	7.2	7.5	7.5	7.0	6.9	5.5
Asphalt content (%)		5.2	6.0	5.4	4.7	4.2	3.8	4.2	3.8
Dust/AC ratio		1.44	1.18	1.33	1.60	1.79	1.84	1.64	1.45
Thickness (in.)		2.3	2.1	2.1	1.3	1.6	2.9	1.6	5.8
Density (pcf)		153.3	150.4	149.9	148.6	151.1	155.0	149.1	152.0

Table 10
Recovered Asphalt Cement Properties - Sondrestrom Air Base

Material Property	Item 1					Item 3				
	Sample 1			Sample 2		Sample 1			Sample 2	
	Original	Surface	Intermediate	Surface	Intermediate	Original	Surface	Intermediate	Surface	Intermediate
Penetration										
39°F (0.1 mm)	--	57	41	46	49	--	62	64	62	53
77°F (0.1 mm)	356	126	87	86	108	331	139	149	128	120
Viscosity										
140°F (P)	250	755	1524	936	881	250	836	716	786	803
275°F (cSt)	133	265	362	290	291	156	270	263	264	278
Softening Point (°F)	--	111	115	113	115	--	106	109	111	109
PVN	-0.5	-0.6	-0.5	-0.9	-0.6	-0.3	-0.5	-0.4	-0.6	-0.6
PI	--	6.4	6.8	7.1	6.4	--	6.3	6.2	6.7	6.3

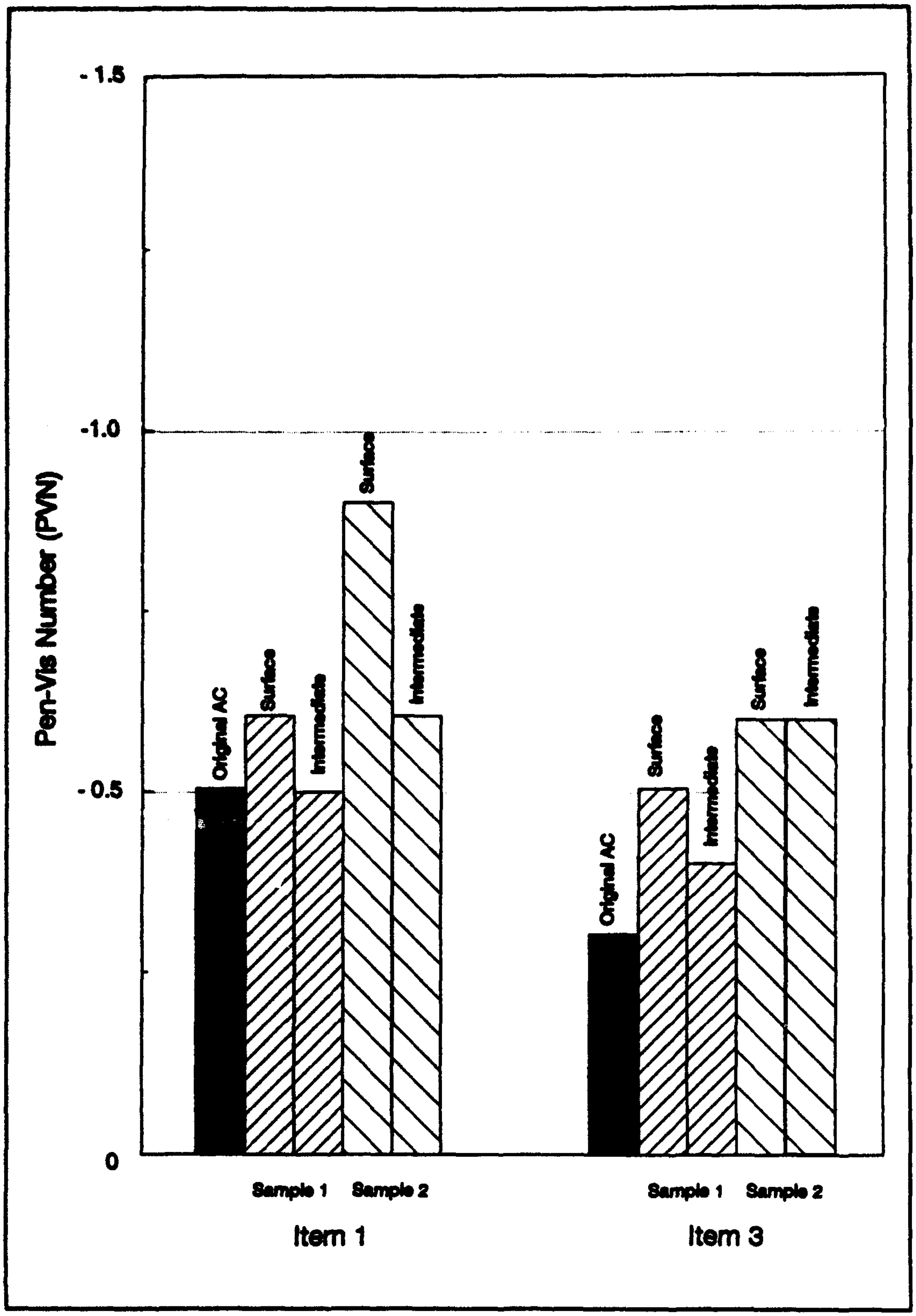


Figure 22. Pen-Vis Numbers for asphalt cements at Sondrestrom Air Base

5 Uncertainties of PVN Criteria

As mentioned earlier in this report, the PVN criteria was originally established in Canada as a means of characterizing the temperature susceptibility of asphalt cements refined from Canadian crude oil sources. Other transportation agencies within the United States, including those representing the U. S. Army Corps of Engineers, have adopted the PVN criteria for use in very cold climates regardless of the asphalt cement's crude oil source. Initial experience has shown that the PVN criteria has been beneficial in several military airfield pavement applications. Some recent experiences in the laboratory and in the field have highlighted some potential problems with the PVN. Pen-vis numbers and the physical properties they are intended to represent have been found to be susceptible to distortion when the asphalt cement is modified with additives.

Laboratory Studies

Pen-Vis numbers were calculated for modified asphalt cements containing additives in a recent study conducted at WES for the U. S. Air Force (Anderton 1990). Three different AC-20 grade asphalt cements, each with different levels of measurable temperature susceptibility, were modified with four different additive materials. The results of these tests, listed in Table 11, raise some important questions about the validity of PVN values when the asphalt cement is modified with additives.

It would appear from the data in Table 11 that with the exception of the oxidant modifier, the temperature-susceptibility of different quality asphalt cements can be significantly reduced through modification with additives. This premise is unproven in the field and is refuted by several recent laboratory studies (Goodrich 1990 and Rollings 1994). Recent innovations in laboratory equipment designed to measure the rheological properties of asphalt cements at low service temperatures have helped to shed more light on this issue.

Table 11
Pen-Vis Numbers from USAF-WES Modifier Study

Asphalt Source	Modifier Type				
	None	Oxidant	SBS	LDP	EVA
1	-1.66	-1.55	0.34	-0.78	-1.18
2	-0.14	-0.28	1.42	1.34	0.55
3	-0.45	-0.41	1.13	0.88	0.13

Modifiers:
Oxidant = oil-based soap with soluble manganese
SBS = styrene-butadiene-styrene
LDP = low-density polyethylene
EVA = ethylene-vinyl acetate

In his report for a major asphalt producer in the United States (Goodrich 1990), Goodrich concludes that "above about 10 deg C, the properties of modified asphalt are influenced by the modifier. Below about 10 deg C, the properties of the modified asphalts are dominated by the base asphalt itself." This implies that the expected increase in PVN from modification, as supported by the data in Table 11, has little if anything to do with actual low-temperature pavement performance. This further implies that an asphalt cement with an unacceptable PVN value can be modified with any number of additives so that the PVN value is acceptable without significantly altering low-temperature performance. This could become a serious deficiency in the use of PVN criteria in the near future as asphalt producers become more familiar with asphalt modifiers and their marketing advantages.

The conclusions cited by Goodrich regarding the ineffectiveness of asphalt modification on low-temperature pavement properties is supported by similar research conducted at WES and reported by Rollings (Rollings 1994). Numerous rheological tests have been conducted at WES on various combinations of asphalt cements and modifiers using the dynamic shear rheometer (DSR). Figure 23 is a typical graphical representation of a series of DSR tests designed to determine the effects of various levels of modification on a common asphalt cement. Although the reference temperature is held constant for all tests at 10 deg C, the frequency range can be used to directly relate to temperature. In this case, the low-frequency range relates to high-temperature performance and the high-frequency range relates to low-temperature performance. The storage modulus (G′) of the asphalt cement is primarily a measure of the elastic response of the material to an imposed dynamic load. Storage modulus should be higher in the low-frequency (high temperature) range to improve deformation resistance and lower in the high-frequency (low temperature) range to reduce stiffness. Figure 23 clearly shows the implied performance improvements imparted by asphalt modification to be much greater in the high-temperature range than in the low-temperature range. Further laboratory studies and field tests should determine the significance of these storage modulus differences. Initial indications from these studies at WES are that the low-temperature performance improvements to be gained by asphalt modification would be marginal at best.

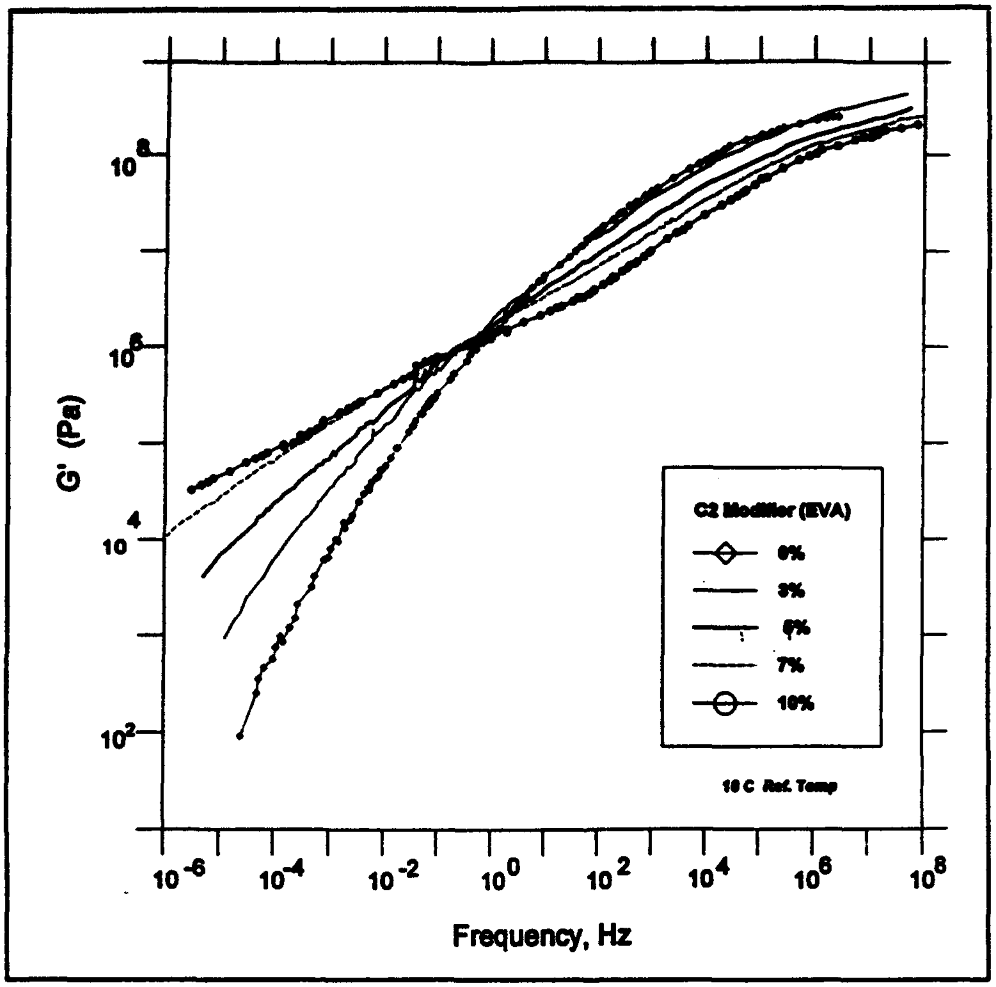


Figure 23. Storage modulus versus frequency for various levels of asphalt modification

Field Experience

In 1992, WES conducted a laboratory forensic evaluation of asphalt cement and asphalt concrete samples from Eielson AFB, AK (Anderton and Lewandowski 1992). The asphalt samples represented materials from an airfield parking apron that was experiencing thermal cracking problems one year after construction. The construction specifications used for this project included the PVN arctic-grade asphalt cement requirement. Several factors prompted the U.S. Army Engineer District, Alaska to request the forensic evaluation:

a. Alaska's experience with arctic-grade asphalt cements suggested that thermal cracking after one year of service was highly unusual.

b. Other asphalt pavements constructed at Eielson AFB using arctic-grade asphalt cements had a minimal amount of thermal cracking after several years of service.

c. During preconstruction material evaluations, three separate submittals of asphalt cement were made by the contractor before a cement passing the minimum -0.20 PVN criteria was found and approved.

Laboratory tests for this forensic evaluation included spectrographic and chromatographic analyses to determine molecular and chemical profiles of the asphalt cements. Penetration and viscosity tests were also performed in order to calculate PVN data. The asphalt cement tested was recovered from field cores cut from the 1-yr old asphalt pavement at Eielson. Additional PVN data was supplied for all three asphalt cements submitted before construction for acceptance testing, including the asphalt cement reported to have been used during construction. Also, a sample of the original asphalt cement which passed acceptance testing was secured for spectrographic and chromatographic evaluation.

The penetration, viscosity, and PVN data from the field core samples and the preconstruction submittal samples are given in Table 12. A direct comparison of the PVN data is allowable since PVN is considered a life long fingerprint of a given asphalt cement's temperature susceptibility (Hass, et al 1987, McLeod 1987, Kandal and Koehler 1985). This means that the PVN value of a given asphalt cement should be near the same value when tested at the refinery, after plant mixing at elevated temperatures with hot aggregates, and after years of service in the field as part of the pavement.

Table 12
PVN Data From Eielson AFB Forensic Evaluation

Sample No.	Penetration at 77°F (0.1 mm)	Viscosity at 275°F (centistokes)	PVN
Precon 1	144	186	-1.02
Precon 2	189	182	-0.74
Precon 3[1]	246	260	+0.27
Core 1-S[2]	79	280	-1.01
Core 1-I	93	237	-1.10
Core 2-S	101	276	-0.78
Core 2-I	132	238	-0.72
Core 3-S	124	210	-0.99
Core 3-I	135	235	-0.71

[1] Accepted as asphalt cement to be used during construction.
[2] Cores taken in three areas and separated into two layers before testing. (S - surface layer; I - intermediate or bottom layer)

By comparing the PVN data in Table 12, it is easy to conclude that the PVN range of the field cores is representative of the PVN range of the two asphalt cements which failed the preconstruction acceptance tests. None of the field core PVN values come close to the +0.27 value of the accepted asphalt cement. The spectrographic and chromatographic analyses provided further explanations for this discrepancy by identifying a common additive in the accepted Precon 3 sample and in each of the field core samples. The amount of the additive in the asphalt cement was determined to be approximately 2 percent by weight and similar in chemical structure to a linear hydrocarbon acetate (i.e., some type of petroleum-based oil). Alaska District personnel had reported that the use of additives such as this is common practice in Alaska since the local sources of unmodified asphalt cements typically do not meet the -0.20 minimum PVN criteria.

The probable scenario at Eielson AFB determined by this forensic evaluation points out one of the most significant dangers in using the PVN criteria. It seems likely that at Eielson, after two failed submittals of asphalt cement, someone merely modified an otherwise unacceptable asphalt cement to meet the PVN criteria. In such a case, the bulk of the additive would likely evaporate during the extended high-temperature mixing phase of the hot mix asphalt production. The result of this scenario was an asphalt pavement that performed poorly at low temperatures as the unmodified base asphalt cement properties would have predicted had the additive not been used to disguise an unacceptable PVN.

6 Conclusions and Recommendations

Conclusions

Based on the findings of the literature review, the following conclusions were made on the effectiveness of special grade asphalt cements to reduce thermal cracking:

a. Low-temperature transverse cracking occurs when the temperature induced tensile stress in the asphalt concrete exceeds the tensile strength of the asphalt concrete.

b. Asphalt cement grade is the most significant design parameter for minimizing low-temperature cracking of asphalt pavements.

c. PVN classification is a widely used and accepted method for determining the temperature susceptibility of an asphalt cement in cold climates.

d. Laboratory studies have indicated that asphalt modification does increase PVN values, but has little effect on low-temperature performance. Asphalt modification can increase an unacceptable PVN value and make an asphalt cement acceptable according to the PVN criteria without significantly improving the pavement performance.

Based on the results of the field inspections and material evaluations, the following conclusions were made on the effectiveness of special grade asphalt cements:

a. No PVN values from recovered asphalt cements met the minimum criteria for severe cold climates (-0.2), but several asphalt cements did meet the minimum criteria for moderate cold climates (-0.5).

b. The recovered PVN values for standard grade asphalt cements were -1.3 while the special grade asphalt cements ranged between -0.3 and -0.8.

c. Full depth reconstructed pavements had better pavement surface conditions (less cracking) than asphalt overlay pavements; special grade asphalt cements had little or no effect on preventing or reducing reflective cracks.

d. For an asphalt overlay, the type of asphalt cement does not have a great effect on pavement surface condition, i.e., transverse and longitudinal cracking.

e. PVN values for recovered asphalt cements were approximately the same as PVN values for the original asphalt cements. PVN values were not affected by plant production (heat) and weathering.

f. PI values for recovered asphalt cements were much higher than typical values for asphalt cements. The PI values were affected by plant production (heat) and weathering.

g. Field experience at Eielson AFB and related forensic laboratory testing showed that asphalt modification can disguise an unacceptable PVN value.

Recommendations

Based on the conclusions derived from the results of this study, the following recommendations are made:

a. PVN criteria for all cold weather paving should be reduced to -0.5. Satisfactory pavement performance has been achieved in severe cold climates with asphalt cements having PVN values lower than -0.2

b. Asphalt overlay projects should not be required to use PVN criteria but judged on site for specific needs and costs, since transverse and longitudinal reflective cracks will occur before thermal cracks develop.

c. If PVN criteria are required, special provisions for forensic testing should be made to insure asphalt cement has not been modified to disguise an unacceptable asphalt cement.

d. Due to the advent of asphalt additives and modifiers, the PVN criteria has become vulnerable and cannot adequately separate temperature-susceptible asphalts from non-temperature susceptible asphalts. Research is needed to establish new criteria based on rheological properties that can be used to specify the best asphalt cement for cold climates.

e. Additional inspections and evaluations should be conducted to evaluate long term performance (10-15 years) of these airfield pavements.

f. New SHRP criteria should be studied to determine applicability to airfield pavements in cold climates.

References

Anderton, G. L. (1990). "Evaluation of asphalt binder modifiers," Miscellaneous Paper GL-90-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Anderton, G. and Lewandowski, L. (1993). "Additives in bituminous materials and fuel-resistant sealers," Technical Report DOT/FAA/RD-93/30, U.S. Department of Transportation, Federal Aviation Administration, Washington, DC.

Buncher, M. S., Melko, F., Crompton, R. E., and Lee, E. C. (1990). "Airfield Pavement Evaluation Elmendorf Air Force Base Alaska," Air Force Engineering and Services Center, Tyndall Air Force Base, FL.

Department of the Army, U.S. Army Corps of Engineers. (1990). "Selecting asphalt cements," Engineering Technical Letter 1110-1-139, Washington, DC.

Finn, F., Nair, K., and Hilliard, J. (1978). "Minimizing premature cracking in asphaltic concrete pavement," National Cooperative Highway Research Program Report 195, TRB, Washington, DC.

Goodrich, J. L. (1990). "What is the purpose of modifying asphalt with polymers?," Chevron Research and Technology Company, Richmond, CA.

Halstead, W. (1963). "The relation of asphalt ductility to pavement performance," Proceedings of the Association of Asphalt Paving Technologists, Vol. 32, Feb. 1963, pp. 247-270.

Haas, R., Meyer, F., Assaf, G., and Lee, H. (1987). "A comprehensive study of cold climate airport pavement cracking," Proceedings of the Association of Asphalt Paving Technologists, Vol 56, pp 198-245, St. Paul, MN.

Harrison, J. A. (1990). "Condition Survey, Wainwright Army Airfield (Fort Wainwright), Fairbanks, Alaska," Miscellaneous Paper GL-90-16, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Janoo, V. (1990). "Use of soft grade asphalts in airfields and highway pavements in cold regions," U.S. Army Cold Regions Research and Engineering Laboratory.

Kandhal, P. S. and Koehler, W. C. (1985). "Effect of rheological properties of asphalts on pavement cracking," Paper presented to American Society for Testing and Materials Symposium on Rheological Properties of Asphalts and their Effects on Mixture Properties and Pavement Performance, Nashville, TN.

McLeod, N. (1976). "Asphalt cements: Pen-Vis number and its application to moduli of stiffness," Journal of Testing and Evaluation, Canada.

McLeod, N. W. (1987). "Employing paving asphalt temperature susceptibility in the structural design of asphalt pavements," Paper prepared for Sixth International Conference on the Structural Design of Asphalt Pavements, Ann Arbor, MI.

Millard, K. S., Melko, F. M., Lee, E. C., and Kortum, S. A. (1989). "Airfield Pavement Evaluation Sondrestrom Air Base Greenland," Air Force Engineering and services Center, Tyndall Air Force Base, FL.

Pfeiffer, J., and van Doormaal, P. (1936). "Rheological properties of asphaltic bitumens," *Journal of the Institute of Petroleum*, Vol 22.

Rollings, R. S. (1994). "Rheology of paving materials," Draft Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

State of the Art Report 7. (1988). "Low-temperature properties of paving asphalt cements," Transportation Research Board, National Research Council, Washington, DC.

The Asphalt Institute Research Report No. 81-1. (1981). "Design techniques to minimize low-temperature asphalt pavement transverse cracking," USA.

Vinson, T., Janoo, V., Haas, R. (1989). "Summary report on low temperature and thermal fatigue cracking," Strategic Highway Research Program (SHRP), National Research Council.

Appendix A
ETL 1110-1-139
Selecting Asphalt Cements

CEMP-ET

DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, D.C. 20314-1000

Engineer Technical
Letter 1110-1-139

22 June 1990

Engineering and Design
SELECTING ASPHALT CEMENTS

1. Purpose. This letter updates guidance for selecting asphalt cements for pavement construction as outlined in section 6-2 of TM 5-822-8/AFM 88-6, Chapter 9, "Bituminous Pavements Standard Practice".

2. Applicability. This letter is applicable to all HQUSACE elements and field operating activities (FOA) having Army, Air Force and military and civil works construction design responsibility.

3. References. The following references provide necessary general information, definitions and design guidance for pavements:

a. TM 5-822-5/AFM 88-7, Chap. 3.

b. TM 5-822-8/AFM 88-6, Chap. 9.

c. TM 5-818-2/AFM 88-6, Chap. 4.

d. ASTM D 946.

e. ASTM D 3381.

4. Background. Asphalt cements used in pavement construction are currently graded or classified on the basis of two different systems: penetration or viscosity. Within the continental United States (CONUS), penetration grading of asphalt cement has been generally replaced by viscosity grading. Outside the continental United States (OCONUS), penetration grading of asphalt cements is still common. Because of effects of the grading system change and the accumulation of many years of pavement performance data base on the penetration grading system, this letter is needed to provide guidance in selecting asphalt cements.

5. Action to be Taken. Pending publication of permanent media guidance, the criteria provided at Enclosures 1 and 2 will be used as an interim for selecting asphalt cements. Selection of asphalt cement grades for Army facilities in cold regions will be coordinated with HQUSACE (CEMP-ET), WASH, DC 20314-1000. Approval and selection of asphalt cements for Air Force airfields will be coordinated with the appropriate CEMP-ET mandatory center of expertise.

This ETL supersedes ETL 1110-3-369, 28 March 1986.

6. Implementation. This letter will have routine application for military construction as defined in paragraph 6c, ER 1110-345-100.

FOR THE COMMANDER:

2 Incls

HERBERT H. KENNON
Chief, Engineering Division
Directorate of Military Programs

Chapter 1
SELECTING ASPHALT CEMENTS

General

Asphalt cements for use in pavement design and construction are graded or classified in one of two ways. Grading can be done on the basis of penetration depth of a standard test needle into asphalt cement at a standard test temperature. The other method of grading is based on the use of a viscosity test. Currently, in the continental United States (CONUS), viscosity grades of asphalt are common. However, outside the continental United States (OCONUS), penetration grades of asphalt may be more easily obtained. Tables 1 and 2 give specifications for the two types of viscosity graded asphalts. Table 3 gives specifications for penetration grades. All three tables are from current standards of ASTM D 3381 for viscosity grades and ASTM D 946 for penetration grades.

Selecting a grade of asphalt cement should be based on several items. Among the most important are climate, traffic conditions, economics of asphalt availability, and previous regional experiences. Traffic conditions and economic considerations will vary from project to project, but environmental conditions and regional experiences should have some similarity. For example, warm and hot regions should have similar experiences in avoiding unstable asphalt concrete mixes during the summer months, and cold regions should have similar experiences in avoiding crack-prone pavements during winter months.

Asphalt Cement Selection by Temperature Region

Table 4 gives guidance for selecting an asphalt cement by temperature region. Climatological data are required to provide input into the selection method. First, average monthly maximum temperature data are required to compute a pavement temperature index (PTI).[1] When project locations have average monthly maximum temperatures above 75° F (23.9° C), the PTI is defined as the sum of the monthly increments exceeding 75° F (23.9° C). Conversely, when no monthly temperature exceeds 75° F (23.9° C), the PTI is defined as the difference between the highest average maximum temperature for the warmest month and 75° F (23.9° C). Enclosure 2 (Example 1) shows an example of PTI computations.

When it is determined that a project will exist in a cold region, as defined in Table 4, additional climate data are required. For the project area under consideration, a design air freezing index (DFI) is also required to further satisfy cold region requirements. (Reference TM 5-818-2/AFM 88-6, Chap. 4 for determination of DFI.) Cold regions are areas where the penetration-viscosity number (PVN) method is used to aid in selecting an asphalt cement.

---

[1] Headquarters, Departments of the Army and the Air Force, Bituminous Pavements Standard Practice, TM 5-822-8/AFM 88-6, Chap. 9.

Table 1

Requirements for Asphalt Cement Viscosity Graded at 140° F (60° C)[1]

(Grading Based on Original Asphalt)

Test	Viscosity Grade					
	AC - 2.5	AC - 5	AC - 10	AC - 20	AC - 30	AC - [illegible]
Viscosity, 140° F (60° C), P	250 ± 50	500 ± 100	1,000 ± 200	2,000 ± 400	3,000 ± 600	4,000 ± [illegible]
Viscosity, 275° F (135° C), min, cSt	125	175	250	300	350	400
Penetration, 77° F (25° C), 100 g, 5 s, min	220	140	80	60	50	40
Flash point, (Cleveland open cup), min, ° F (° C)	325 (163)	350 (177)	425 (219)	450 (232)	450 (232)	450 (232)
Solubility in trichloroethylene, min, percent	99.0	99.0	99.0	99.0	99.0	99.0
Tests on residue from thin-film oven test viscosity, 140° F (60° C), max, P	1,250	2,500	5,000	10,000	15,000	20,000
Ductility, 77° F (25° C), 5 cm/min, min, cm	100[2]	100	75	50	40	25

[1] From American Society for Testing and Materials Standard Specification D 3381-83, Table 2.

[2] If ductility is less than 100, material will be accepted if ductility at 60° F (15.5° C) is 100 minimum at a pull rate of 5 cm/min.

Table 2

Requirements for Asphalt Cement Viscosity Graded at 140° F (60° C)[1]

(Grading Based on Residue from Rolling Thin-Film Oven Test)

Tests on Residue from Rolling Thin-Film Oven Test[2]	Viscosity Grade AR-1000	AR-2000	AR-4000	AR-8000	AR-16000
Viscosity, 140° F (60° C), P	1,000 ± 250	2,000 ± 500	4,000 ± 1,000	8,000 ± 2,000	16,000 ± 4,000
Viscosity, 275° F (135° C), min, cSt	140	200	275	400	550
Penetration, 77° F (25° C), 100 g, 5 s, min	65	40	25	20	20
Percent of original penetration, 77° F (25° C), min	--	40	45	50	52
Ductility, 77° F (25° C), 5 cm/min, min, cm	100[3]	100[3]	75	75	75
Tests on original asphalt: Flash point, (Cleveland open cup), min, ° F (° C)	400 (205)	425 (219)	440 (227)	450 (232)	460 (238)
Solubility in trichloroethylene, min, percent	99.0	99.0	99.0	99.0	99.0

[1] From American Society for Testing and Materials Standard Specification D 3381-83, Table 3.

[2] Thin-film oven test may be used but the rolling thin-film oven test shall be the referee method.

[3] If ductility is less than 100, material will be accepted if ductility at 60° F (15.5° C) is 100 minimum at a pull rate of 5 cm/min.

Table 3

Requirements for Asphalt Cement Graded by Penetration at 77° F (25° C)[1]

(Grading Based on Original Asphalt)

Test	Penetration Grade									
	40 - 50		60 - 70		85 - 100		120 - 150		200 - [illegible]	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	[illegible]
Penetration at 77° F (25° C) 100 g, 5 s	40	50	60	70	85	100	120	150	200	300
Flash point, ° F (Cleveland open cup)	450	--	450	--	450	--	425	--	350	--
Ductility at 77° F (25° C) 5 cm/min, cm	100	--	100	--	100	--	100	--	100[2]	--
Solubility in trichloroethylene, percent	99.0	--	99.0	--	99.0	--	99.0	--	99.0	--
Retained penetration after thin-film oven test, percent	55+	--	52+	--	47+	--	42+	--	37+	--
Ductility at 77° F (25° C) 5 cm/min, cm after thin-film oven test	--	--	50	--	75	--	100	--	100[2]	--

[1] From American Society for Testing and Materials Standard Specification D 946-82, Table 1.

[2] If ductility at 77° F (25° C) is less than 100 cm, material will be accepted if ductility at 60 ° F (15.5° C) is 100 cm minimum at the pull rate of 5 cm/min.

Table 4

Asphalt Cement Selection Criteria Based on Pavement Temperature Index

Pavement Temperature Index, Cumulative °F (°C)	Temperature Region	Asphalt Cement Selection Criteria
Less than 30 (16.7)	Cold	Penetration-viscosity method for cold regions (Table 5)
30 to 80 (16.7 to 44.4)	Warm	85 to 100 penetration (original asphalt)
Greater than 80 (44.4)	Hot	60 to 70 penetration (original asphalt)

DFI's are used to differentiate between climates in cold temperature regions. A DFI of 3,000 degree-Fahrenheit-days (degree-days) or 1,667 degree-Celsius-days is used as the delineation between moderately cold and severely cold (extremely cold) climates. Moderately cold climates have DFI's up to 3,000 degree-days, and severely cold climates have DFI's greater than 3,000 degree-days.

Penetration-Viscosity Number: For Cold Regions

Penetration-Viscosity Number (PVN), also called Pen-Vis Number, is an empirical correlation between asphalt cement factors and low temperature pavement cracking experiences in Canada. Asphalt cement factors considered in the original correlation were penetrations at 77° F (25° C), viscosity at 275° F (135° C), and penetration index.[2] McLeod[3] proposed PVN for selecting asphalt cements to prevent low temperature cracking of asphalt concrete pavements. The PVN method is used to quantify temperature susceptibility of an asphalt cement and estimate its ability to prevent low-temperature cracking.

Required input data are penetration at 77° F (25° C) and kinematic viscosity at 275° F (135° C). Figure 1 allows estimation of PVN for asphalt cements in cold regions. Table 5 provides minimum PVN selection criteria for asphalts in cold regions. Table 5 and Figure 1 should always be used when selecting asphalts for use in cold regions. Table 5 also shows requirements for airfields and roads and other pavements. A design index is required for

[2] Ad Hoc Committee, "Design Techniques to Minimize Low-Temperature Asphalt Pavement Transverse Cracking," Research Report 81-1, Asphalt Institute, December 1981.

[3] McLeod, N. W., "A 4-Year Survey of Low-Temperature Transverse Pavement Cracking on Three Ontario Test Roads," Proceedings, Association of Asphalt Paving Technologists, Vol. 41, 1972.

Table 5

Minimum PVN Selection Criteria for Asphalt Cemen · in Cold Region Use

Cold Region	Airfields	Roads and Other Pavements by Design Index ≤ 4	Roads and Other Pavements by Design Index > 4
Moderate cold (DFI ≤ 3,000 degree-days*)	-0.5	-0.5	-0.5
Severe cold (DFI > 3,000 degree-days*)	-0.2	-0.5	-0.2

* Degree-Fahrenheit-days (1,667 degree-Celsius-days).

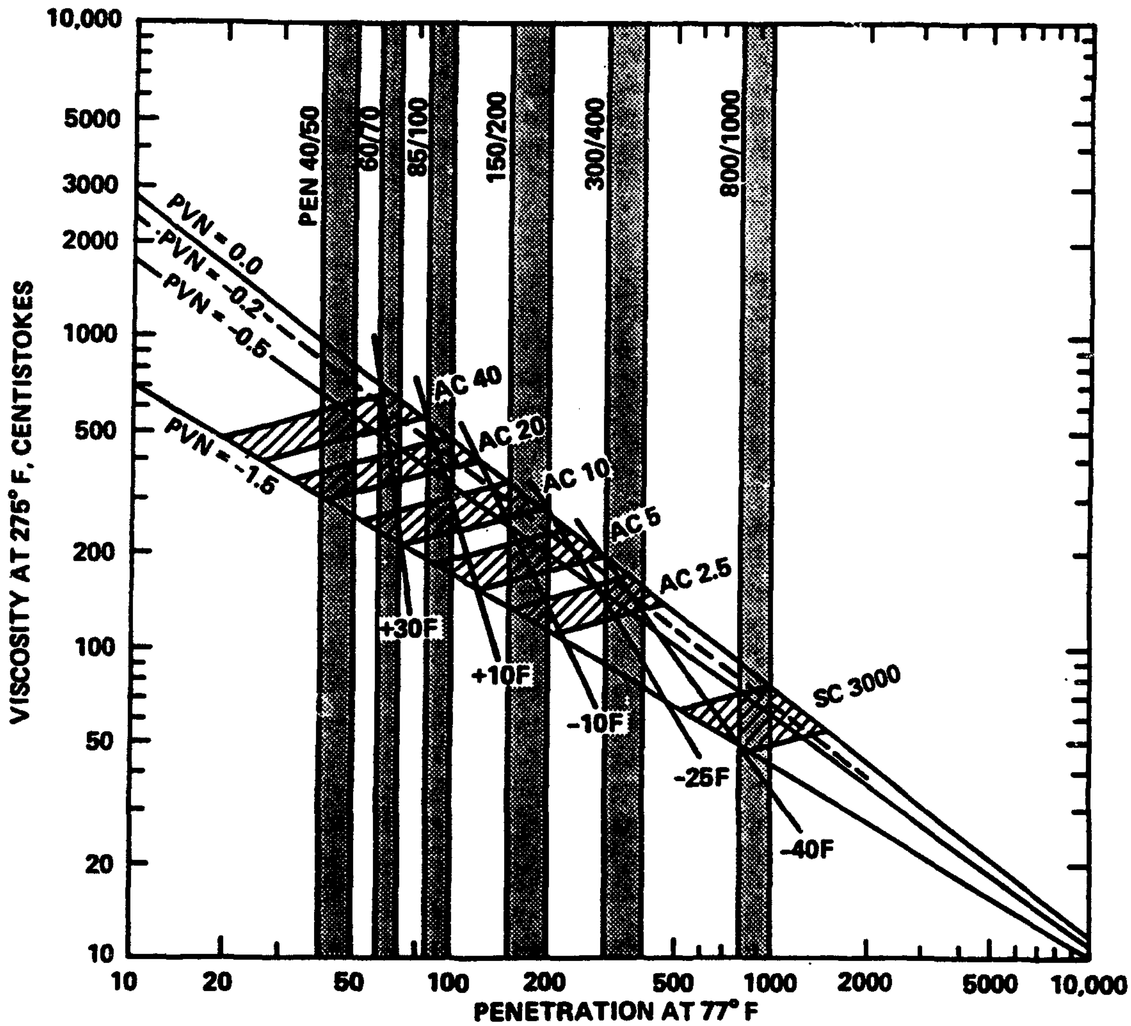


Figure 1. PVN chart for cold region asphalt selection (McLeod 1972)

roads and other pavements; it is an index of traffic estimate and is defined in TM 5-822-5/AFM 88-7, Chap. 3.

Temperature at a 2-in. depth of pavement can be estimated from a DFI for a given project location or site as shown in Figure 2. This "minimum anticipated pavement temperature" and minimum PVN criteria of Table 5 can be used with Figure 1 to select an asphalt cement.

An asphalt with given penetration and viscosity can be checked for satisfying PVN criteria of Table 5 by plotting in Figure 1. If its penetration and viscosity point falls on or above the minimum PVN value and to the right of the minimum anticipated pavement temperature, it is estimated that low temperature contraction cracking of the asphalt concrete layer will be prevented. If it plots to the left of the anticipated pavement temperature, the pavement will likely crack at low temperatures. PVN values should be calculated for more accurate results.

Examples of Asphalt Cement Selection

Enclosure 2 contains examples of asphalt cement selection by use of this Engineer Technical Letter.

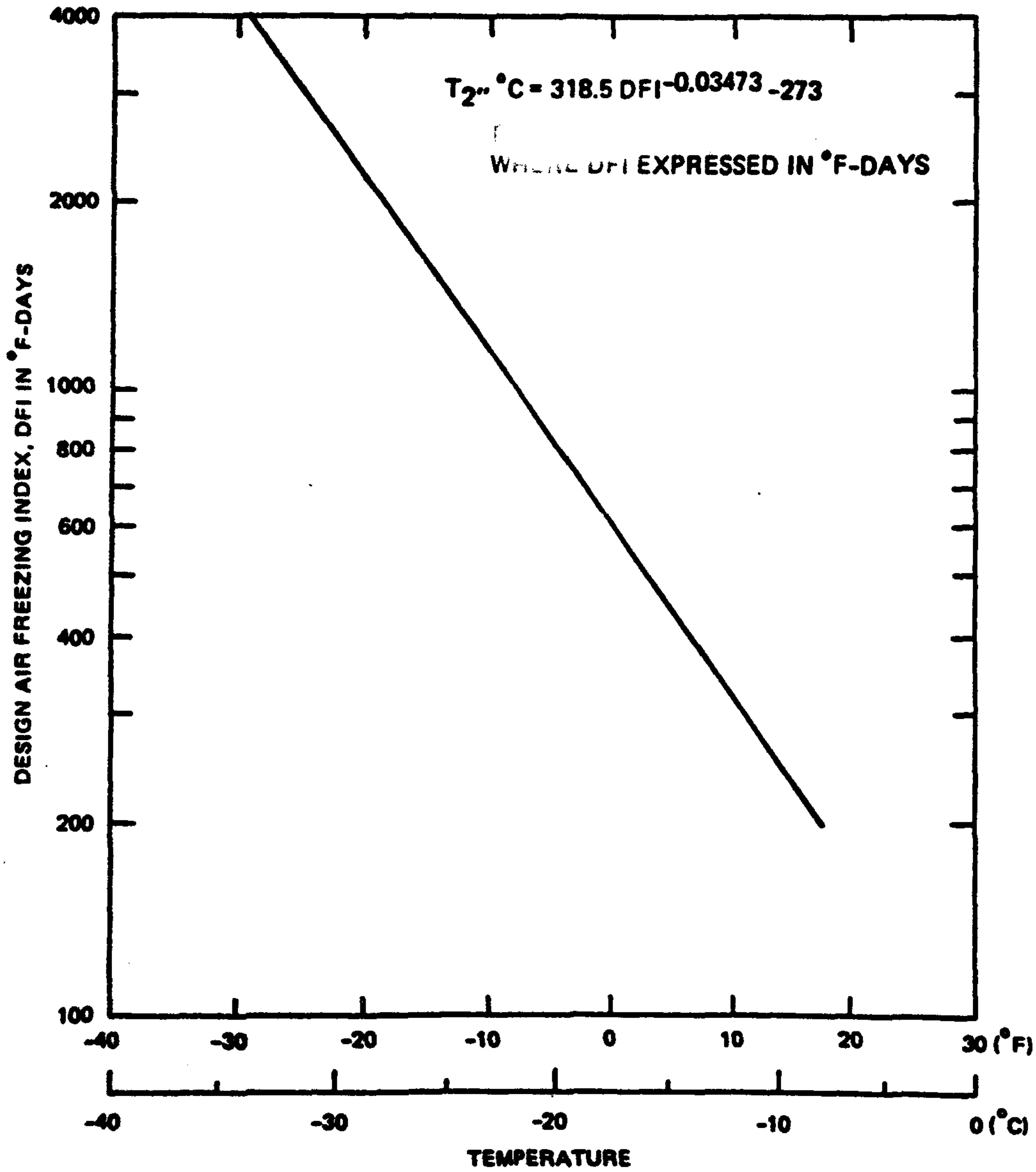


Figure 2. Pavement temperature as a function of design air freezing index

Chapter 2

EXAMPLE ANALYSES FOR SELECTING AN ASPHALT CEMENT

Example 1. Calculating Pavement Temperature Index

The method for calculating the pavement temperature index for two construction sites is given in this example.

The average monthly maximum temperature and the difference above 75° F (23.9° C) for Site A and Site B are given below.

	Site A		Site B	
Month	Avg. Max. Temperature °F	Difference Above 75° F	Avg. Max. Temperature °F	Difference Above 75° F
Jan	60.5	--	29.8	--
Feb	68.5	--	27.8	--
Mar	73.7	--	43.0	--
Apr	79.9	4.9	58.2	--
May	88.5	13.5	67.2	--
Jun	94.5	19.5	70.4	--
Jul	97.6	22.6	77.0	2.0
Aug	92.0	17.0	74.2	--
Sep	90.2	15.2	66.9	--
Oct	80.3	5.3	57.5	--
Nov	74.0	--	43.4	--
Dec	60.3	--	36.8	--
	Cumulative Total	98.0		2.0

The temperature index at these sites is the sum of the increments of average monthly maximums above 75° F; therefore, the pavement temperature index for each site is as follows:

Site A = 98.0, cumulative °F (54.4, cumulative °C)

Site B = 2.0, cumulative °F (1.1, cumulative °C)

Based on Table 4 of Enclosure 1, Site A is a hot region, and Site B is a cold region. Site B requires the use of the PVN method to select an asphalt cement.

Example 2. Asphalt Cement Selection in a Hot Region

A parking lot should be built in a region that has a pavement temperature index of 98, cumulative °F (54.4, cumulative °C).

An asphalt supplier can provide asphalt cements that meet the requirements in Table 1 of Enclosure 1 (from ASTM D 3381). Viscosity and penetration data for the asphalt cements are given below.

	AC-10	AC-20	AC-40
Viscosity, 140° F, P	872	2,200	4,104
275° F, cSt	298	435	605
Penetration, 77° F, 0.1 mm	123	70	46

From Table 4 of Enclosure 1, an asphalt cement that has a penetration of approximately 60 to 70 should be selected. The AC-20 asphalt cement should be selected for this pavement.

Example 3. Asphalt Cement Selection in a Warm Region

A street should be constructed in a region that has a pavement temperature index of 42, cumulative °F (23.3, cumulative °C).

An asphalt supplier can provide asphalt cements that meet the requirements in Table 1 of Enclosure 1. Viscosity and penetration data for the asphalt cements are given below.

	AC-5	AC-10	AC-20
Viscosity, 140° F, P	560	1,120	2,170
275° F, cSt	180	335	450
Penetration, 77° F, 0.1 mm	145	96	70

Based on Table 4 of Enclosure 1, an asphalt cement that has a penetration of approximately 85 to 100 should be selected. The AC-10 asphalt cement is selected.

Example 4. Asphalt Cement Selection in a Cold Region

At Fort Drum, NY, a heavy duty open storage area (design index of 10) for use by 50,000 lb forklift trucks has to be constructed in a region with a pavement temperature index of 2, cumulative °F (1.1, cumulative °C) and a DFI of 2,300 degree-Fahrenheit-days (1,278 degree-Celsius-days) calculated using TM 818-2.

An asphalt supplier can provide two asphalt cements that meet the requirements in Table 1 of Enclosure 1. Viscosity and penetration data for the asphalt cements are given below.

	AC-2.5	AC-5
Viscosity, 140° F, P	280	466
275° F, cSt	140	220
Penetration, 77° F, 0.1 mm	296	240

Analysis and Asphalt Selection

The climatological data allow classification of the site by temperature region and allow an estimate of pavement temperature. According to Table 4 of Enclosure 1, the pavement temperature index classifies the site as a cold region where the PVN method should be used to select the grade of asphalt cement. The DFI allows the use of Figure 2 (Enclosure 1) to estimate a minimum pavement temperature at a 2-in. (5 cm) depth. From Figure 2, a minimum anticipated pavement temperature is about -22° F (-30° C).

Table 5 of Enclosure 1 shows that this cold region can be further classified as a moderately cold region since its DFI is less than 3,000 degree-Fahrenheit-days. Table 5 also indicates that the required PVN of the asphalt selected must be greater than -0.5 for a design index of 10. This will minimize low temperature pavement cracking.

Now, PVN values must be determined for the available asphalt cements. This can be done by either plotting penetration and viscosity at 275° F (135° C) in Figure 1 of Enclosure 1 or by using PVN equations. If the details of Figure 1 are not sufficient to accurately determine PVN values, equations should be used.

The general PVN equation[1] is as follows:

$$PVN = \frac{(L - X)(-1.5)}{(L - M)}$$

where

L = logarithm of viscosity in centistokes at 275° F (135° C) for a PVN of 0.0 at the given penetration

X = logarithm of viscosity in centistokes at 275° F (135° C) of a given asphalt

M = logarithm of viscosity in centistokes at 275° F (135° C) for a PVN of -1.5 at the given penetration

Values of X can be determined directly from asphalt cement viscosity data as provided in this example, but values of L and M are a function of the penetration values of each asphalt. Equations for the values of L and M are:

$$L = 4.25800 - 0.79674 \text{ LOG (PEN)}$$

[1] McLeod, N. W., "Using Paving Asphalt Rheology to Impair or Improve Asphalt Pavement Design and Performance", Asphalt Rheology: Relationship to Mixture, ASTM STP 941, O. E. Briscoe, Ed., American Society for Testing and Materials, Philadelphia, 1987.

$$M = 3.46289 - 0.61094 \text{ LOG (PEN)}$$

where PEN = penetration at 77° F (25° C) of a given asphalt cement.

Calculated PVN values of the two available asphalt cements are:

PVN = -0.638 for AC-2.5

PVN = -0.081 for AC-5

Based on Table 5 of Enclosure 1, an asphalt cement that has a PVN greater than -0.5 and lies on or to the right of the minimum temperature diagonal line should be selected. The AC-5 asphalt cement is selected because it has a PVN of -0.081 and lies to the right of the -22° F temperature diagonal line. This asphalt cement satisfies the requirements of Table 5 and should prevent low-temperature pavement cracking.

Example 5. Asphalt Cement Selection in a Warm Region

A parking lot should be constructed in a region that has a pavement temperature index of 42, cumulative °F (23.3, cumulative °C).

An asphalt supplier can provide asphalt cements that meet the requirements in Table 2 of Enclosure 1. Viscosity and penetration data for the asphalt cements are given below.

	AR-1000	AR-2000	AR-4000
Viscosity, 140° F, P	851	1,962	3,544
275° F, cSt	162	247	334
Penetration, 77° F, 0.1 mm			
Original	141	87	53
Residue	99	55	39

Based on Table 4 of Enclosure 1, an asphalt cement that has a penetration of approximately 85 to 100 should be selected. The AR-2000 asphalt cement is selected based on the original penetration of the material.

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	August 1994	Final report

4. TITLE AND SUBTITLE
Performance of Special Graded Asphalt Cements

5. FUNDING NUMBERS

6. AUTHOR(S)
Randy C. Ahlrich, Lee E. Tidwell, Gary L. Anderton

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

8. PERFORMING ORGANIZATION REPORT NUMBER
Technical Report
GL-94-21

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Department of the Air Force
Air Force Civil Engineering Support Agency
Tyndall AFB, FL 32403-6001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This report documents an investigation that evaluated the performance of special graded asphalt cements in airfield pavements subjected to extreme cold conditions. The study included a literature review, pavement inspections, and laboratory testing of the field samples.

The basis of this study was to determine whether arctic grade asphalt cements minimized the amount and severity of low-temperature cracking. Three locations were chosen for the field evaluation: Wainwright Army Airfield, Alaska; Elmendorf AFB, Alaska; and Sondrestrom Air Base, Greenland. At each location, a visual inspection was conducted to determine the amount and severity of cracking of pavement with standard and special graded asphalt cements. At each site, field samples were taken to evaluate the properties of the in-place asphalt concrete materials. From the data obtained, recommendations were made concerning the use of special graded asphalt cements in DOD pavements.

The findings of this study indicated that PVN criteria should be modified and that the type of construction (full depth repair versus overlay) had greater effect on pavement performance based on cracking than the type of asphalt cement. This study also indicated that asphalt modification affected the PVN values without improving the performance. It is recommended that material testing be conducted to insure asphalt cements have not been modified to disguise an unacceptable asphalt cement.

14. SUBJECT TERMS
See reverse.

15. NUMBER OF PAGES
73

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED		

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

14. (Concluded).

Airfield pavements
Arctic grade asphalts
Asphalt concrete
Cold weather paving
Low temperature cracking
Pen-Vis Number (PVN)
Rheological properties
Temperature susceptibility
Thermal cracking